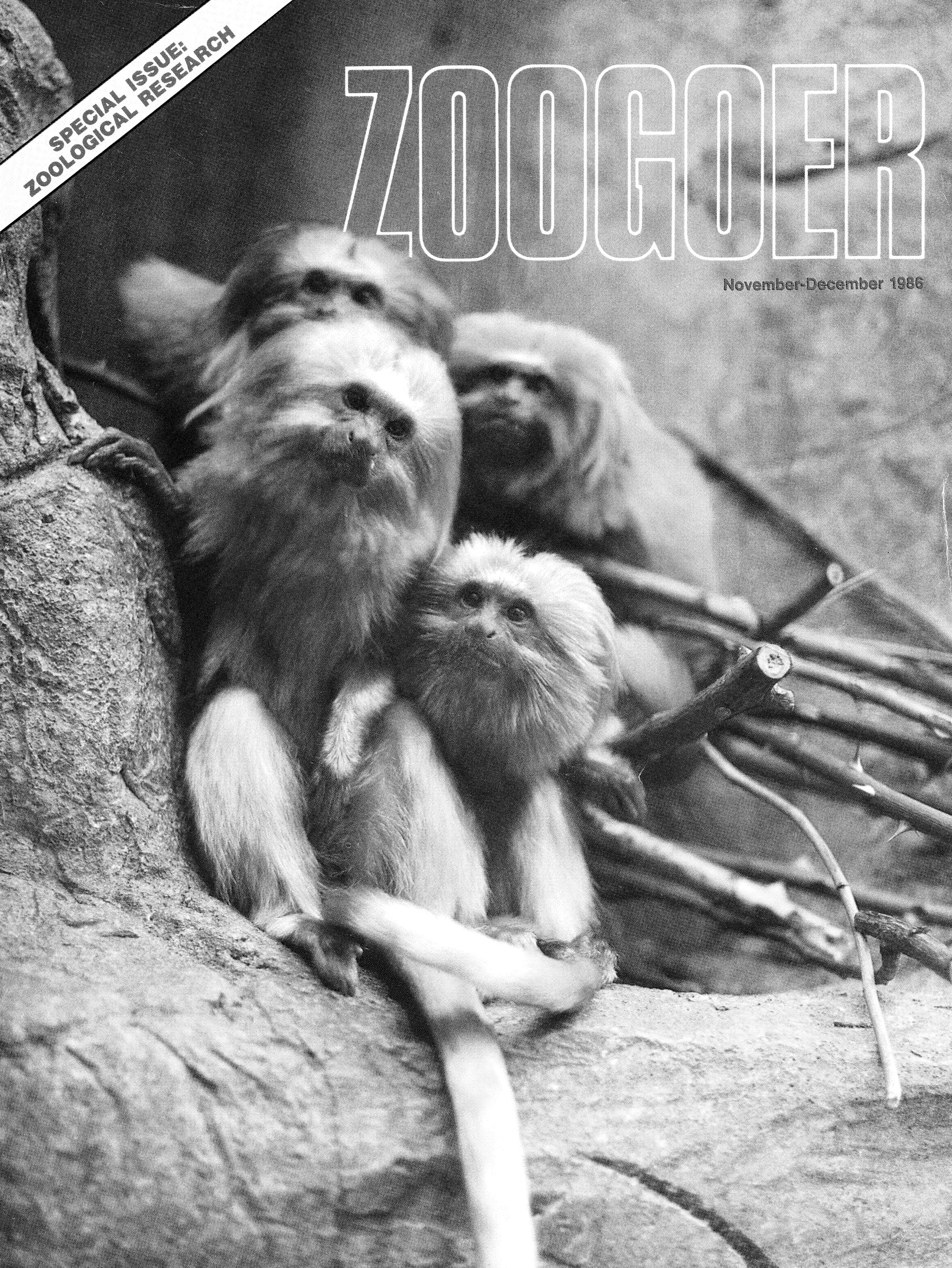
SPECIAL ISSUE:
ZOOLOGICAL RESEARCH

ZOOGOER

November-December 1986



ZOOGOER

SPECIAL ISSUE: ZOOLOGICAL RESEARCH
Volume 15, Number 6, November-December 1986

Friends of the National Zoo is a nonprofit organization of individuals, families, and organizations who are interested in helping to maintain the status of the National Zoological Park as one of the world's great zoos, to foster its use for education, research, and recreation, to increase and improve its facilities and collections, and to advance the welfare of its animals.

ZooGoer [ISSN 06313-416X] is published six times a year by Friends of the National Zoo to promote its aims and programs, and to provide information about FONZ activities to its members, volunteers, and others interested in the purposes of FONZ. The nonmember subscription rate is $7.50 a year. Third class mailing permit no. 6282.

The National Zoological Park is located in the 3000 block of Connecticut Avenue, N.W., Washington, D.C. 20008, (202) 673-4717. Weather permitting, the Zoo is open every day except Christmas. Hours: From May 1 through September 15, grounds are open 8 a.m. to 8 p.m.; buildings, 9 a.m. to 6 p.m. From September 16 through April 30, grounds are open 8 a.m. to 6 p.m.; buildings, 9 a.m. to 4:30 p.m.

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FONZ's Research Support

Dear FONZ Member,

Friends of the National Zoo is especially pleased to publish this special issue of *ZooGoer* on the Department of Zoological Research (DZR) because of the part FONZ has played in the growth and success of research at the National Zoo. Support from FONZ has been a mainstay of DZR's work from the Department's earliest years. In 1986 alone, FONZ research support totalled almost a quarter of a million dollars in financial and volunteer assistance. Also in 1986, FONZ helped sponsor the annual NZP Symposium for the Public on research at the Zoo, which featured presentations by many past and present DZR scientists. Last year's fundraising gala, **ZooFari**, also supported Zoo research by providing funds to help bring Guam rails to our scientists for studies aimed at saving this highly endangered bird.

The work of DZR scientists is central to the work of the entire Zoo, for the "recipes" which guide the management of individual species are often drawn from the research results of DZR scientists in the lab and in the field. By continually improving the lives of the Zoo's hundreds of animal species, DZR scientists also enrich the experience of thousands of human zoo goers. Thus we are justifiably proud of the accomplishments of the National Zoo's Department of Zoological Research, and of the part FONZ has played in its growth.

Sincerely,

Sanders Lewallen

Sanders Lewallen
Executive Director

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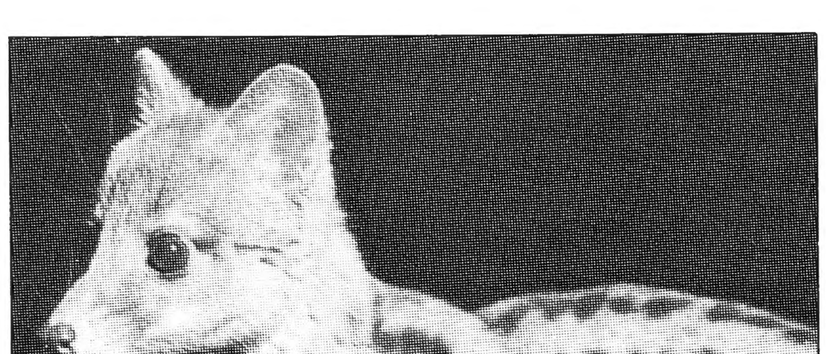


Cover: After intensive survival training at the National Zoo, this golden lion tamarin family was reintroduced to the wild this year. The tamarin reintroduction program was developed through studies at the Zoo's Department of Zoological Research (page 15). Photo by Jessie Cohen, NZP Office of Graphics and Exhibits. Back cover: Autumn in Beaver Valley. Photo by Bruce Kirtley-Hodes.

Jessie Cohen, NZP Graphics

A DZR Nutrition Lab scientist holds a young short-tailed bat.

Introduction

Zoological Research

Devra Kleiman

In 1965, Theodore H. Reed, Director of the National Zoo, hired a young ethologist and mammalogist, John F. Eisenberg, to become the Resident Scientist at the Zoo. The title almost implied that there would never be any other scientists, but later additions to the staff resulted in the creation of the Scientific Research Department, a unit of the Zoo that has achieved an international reputation for the excellence and diversity of its research efforts.

Now called the Department of Zoological Research (DZR), Eisenberg's unit first consisted only of himself, office manager Wyotta Holden, and keeper Gene Maliniak, whose "green thumb" for rearing small mammals resulted in some spectacular breeding successes. They oversaw an assortment of small, sometimes bizarre-looking creatures from every continent—two-toed sloths, solenodons, spiny tenrecs, degus, elephant-shrews, hutias, dwarf maras, and Tasmanian devils, to name a few (see page 11).

The philosophy of the department was clear: to expand biological knowledge about the animals in its stewardship. To do this, researchers studied animals both in the field and in captivity, an approach that has persisted because of the depth of understanding achieved when animals are observed close-up as well as in their natural environment. Indeed, one of Eisenberg's first acts when he came to the Zoo was to leave it—for Madagascar, where he studied the wild tenrecoid insectivores, several species of which came to the Zoo for captive breeding programs. Since then, numerous DZR research projects have involved both a field and a captive component (see page 19).

Research at DZR has also been characterized by the pursuit of multiple answers to questions and the attempt to glean every last bit of information from each animal in the

Dr. Kleiman is the director of the National Zoo's Department of Zoological Research.

collection. Even when animals die of old age, they are stored in a freezer for future study. So a brush-tailed rat whose behavioral development and play I had studied in 1971 with my former student Susan Wilson ended up, almost 14 years after it died, on the dissecting table of Research Associate Ted Grand, who studies the relationship between an animal's physical structure and its behavior.

The importance of maintaining an intellectually stimulating atmosphere has led various DZR staff members to develop liaisons with local universities, where they may teach and supervise graduate students. The constant presence of inquisitive students has fine-tuned our ideas and kept local faculty sympathetic to the unique contribution that zoo research can make to biology. This interaction has also helped us to expand our research purview. While still excelling in the areas of behavior and ecology, researchers now work in the areas of population and molecular genetics (p. 18), functional morphology and energetics (p. 23), evolutionary ecology (p. 20), and nutrition (p. 9).

The statistics that define the productivity of a research department are impressive. By the end of 1985, the DZR had sponsored 14 master's and 25 doctoral degree students and had supported 28 postdoctoral fellows. During 1986, our research activities have involved 16 postdoctoral fellows, 20 graduate students, and 11 undergraduates. These individuals represent an involvement with 27 universities and research projects in 12 countries (p. 19).

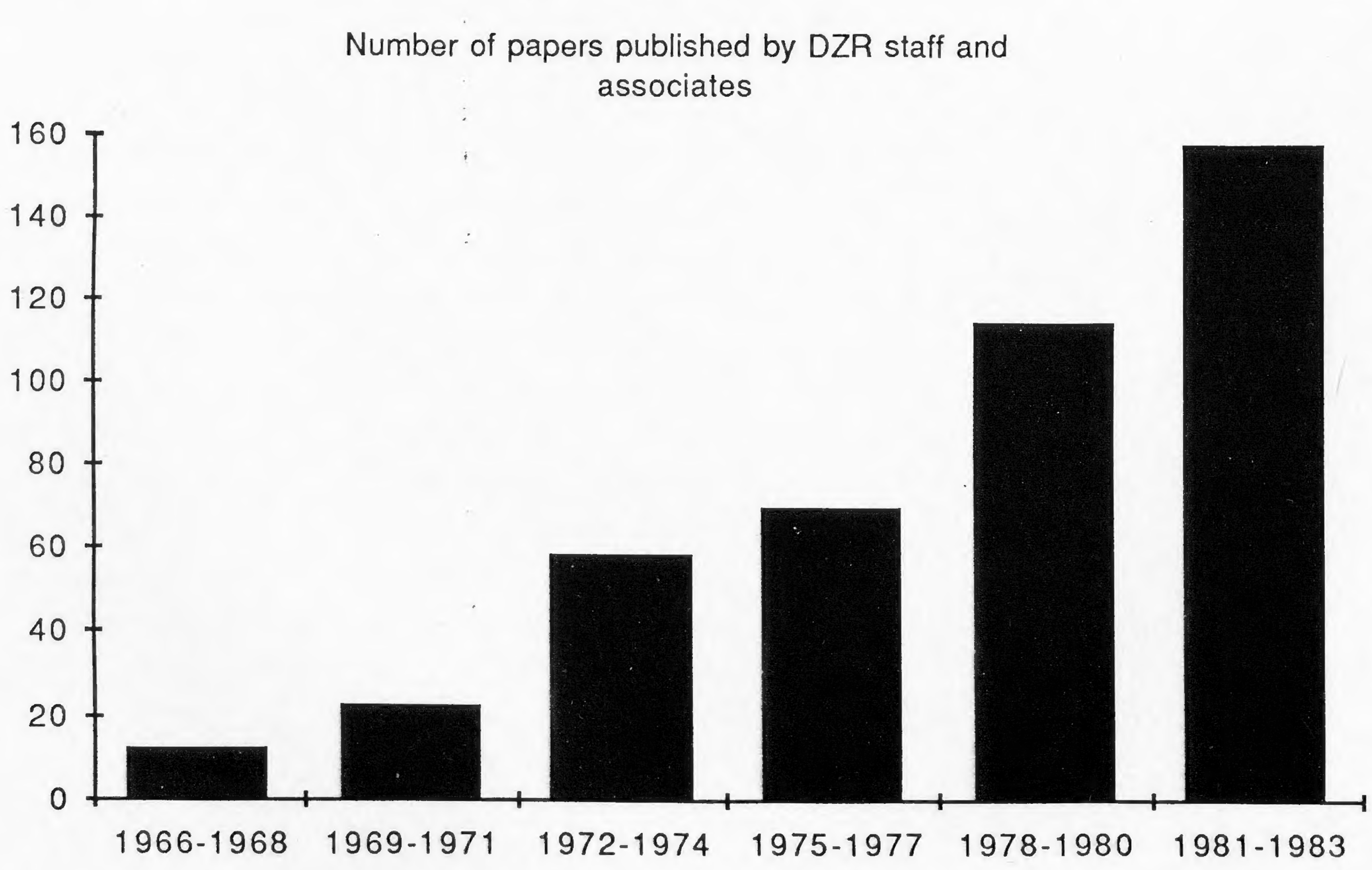
Although DZR's main function is basic research, staff members frequently interact with colleagues from other Zoo departments in joint applied research projects. For example, several of the Zoo's most important breeding programs, including those for the golden lion tamarin, Indian rhinoceros, giant and red pandas, maned wolf, and bush dogs, involve such collaborative work, and DZR personnel have contributed their expertise in helping to develop exhibits in Beaver Valley, the Delicate Hoofed Stock Building, and the Small Mammal, Bird, and Giant Panda houses. The scientists have also presented lectures and developed courses for programs sponsored by the Friends of the National Zoo and the Smithsonian Associates.

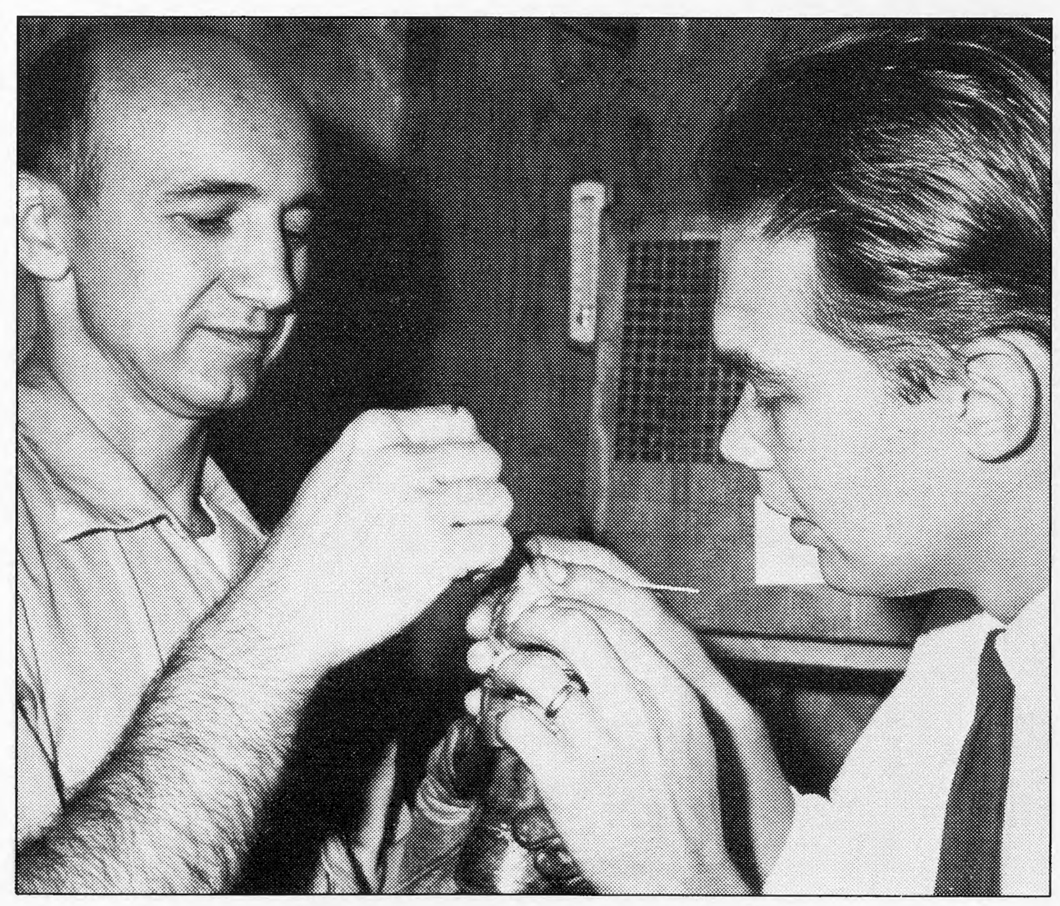
Additionally, department scientists are key figures in several important national and international conservation programs, which include maintaining studbooks, assisting the AAZPA with its Species Survival Plan, participating in several specialist groups for the International Union for the Conservation of Nature and Natural Resources, and advising the World Wildlife Fund on a variety of programs, such as the protection of migratory bird habitat. And DZR has been host to many symposia and workshops on a wide range of topics, of both theoretical and practical interest. Meetings to discuss the ecology of arboreal leaf-eaters, the behavioral ecology of migrant birds, the biology of marmosets and tamarins, the population genetics of wild and captive animals, the social behavior of mammals, and studies of vertebrate ecology from the Northern neotropics have brought together numerous experts to share knowledge and summarize recent advances in diverse fields.

DZR has also applied this accumulated knowledge towards training foreign biologists and wildlife managers in techniques that will enhance conservation efforts worldwide. DZR scientist Rudy Rudran developed the successful Wildlife Management and Training Program, which is taught at the Zoo's Conservation and Research Center at Front Royal, Virginia. This program has already trained hundreds of people from developing countries in modern conservation biology and wildlife management techniques that will greatly improve habitat protection and management.

In addition to staff, students, and visiting scholars, DZR's work is enhanced by the assistance of over 100 FONZ volunteers and interns each year, working on projects that include observing animal behavior and hand-rearing motherless newborns.

While many research projects are collaborative, involving scientists, volunteers, keepers, and interns, the essence of DZR's research is the lone individual making observations on the biology of an animal while trying to integrate the results with what is already known. A single researcher, at the Zoo or thousands of miles away, can discover a fact that can greatly improve a zoo animal's welfare, help a species' chances of survival, or significantly expand a whole field of knowledge. □





Eisenberg (right) and Maliniak examine a murine opossum, 1966.

Sociobiology

Lifestyles of the Rare and Exotic

Susan Lumpkin

People are insatiably curious about people. We avidly follow the parenting and peregrinations of Prince Charles and Lady Di; we wonder in idle moments who Liz Taylor will marry next, and whether Michael Jackson will marry at all. Even the fictional lives of J.R. and Sue Ellen fascinate. And of course, we watch with unflagging interest the behavior—and misbehavior—of our friends and neighbors.

Occasionally, the trials and tribulations of charismatic animals attract similar attention: Ling-Ling and Hsing-Hsing make the news nearly as often as Joe Theisman and Cathy Lee. But scientists in the Zoo's Department of Zoological Research find studying the lifestyles of all sorts of exotic animals as engrossing as any soap opera—and infinitely more exciting.

Dr. Lumpkin is a DZR Research Associate.

The questions that Zoo sociobiologists savor are not unlike those that grip gossip fans. Who mates with whom and how many times? Who deserts and who fools around? How many children are born and who is the father? Who takes care of them? What is the relationship between this female and that male and will it last, or end in separation and second pairings?

But Zoo scientists are not just animal voyeurs. Answers to questions like these are essential to understanding the social behavior of animals and discovering how the great diversity of animal social and mating systems evolved. Successful captive breeding of endangered species depends on this information; so do effective conservation practices for animals in the wild. But what drives DZR biologists into the steamy rainforest to record bird songs and down to the Hospital and Research building's basement to count copulations in the dark is a passionate appreciation of the natural world and an insatiable thirst for knowledge about the ways its inhabitants live.

Obscure Corners

Any one scientist can hope to find only a few pieces of the complex puzzle of animal sociobiology, but over the years, DZR scientists have filled in many parts of the picture, illuminating some of its most obscure corners. Indeed, DZR specializes in describing for the first time the behavior of strange, little-known mammalian species.

Take tenrecs. John Eisenberg and Edwin Gould were the first to publish the secrets of these primitive insect-

Eugene Maliniak

Five-day-old young cling to the nipples of a short bare-tailed opossum, a pouchless marsupial.

Eugene Maliniak

A young streaked tenrec born at DZR was part of the first published study of this primitive species.

Singing in the Vein

In the evolutionary process, it appears that animals developed certain sounds to convey different moods.

Communication is the cornerstone of all social behavior, so the study of animal communication is naturally a major focus of DZR research efforts. Over the years, DZR scientists have deciphered the many and varied messages transmitted by the scent marks and vocalizations of dik-diks, giant pandas, raccoons, and howler monkeys, to name just a few of the mammal species whose communication has come under scrutiny here.

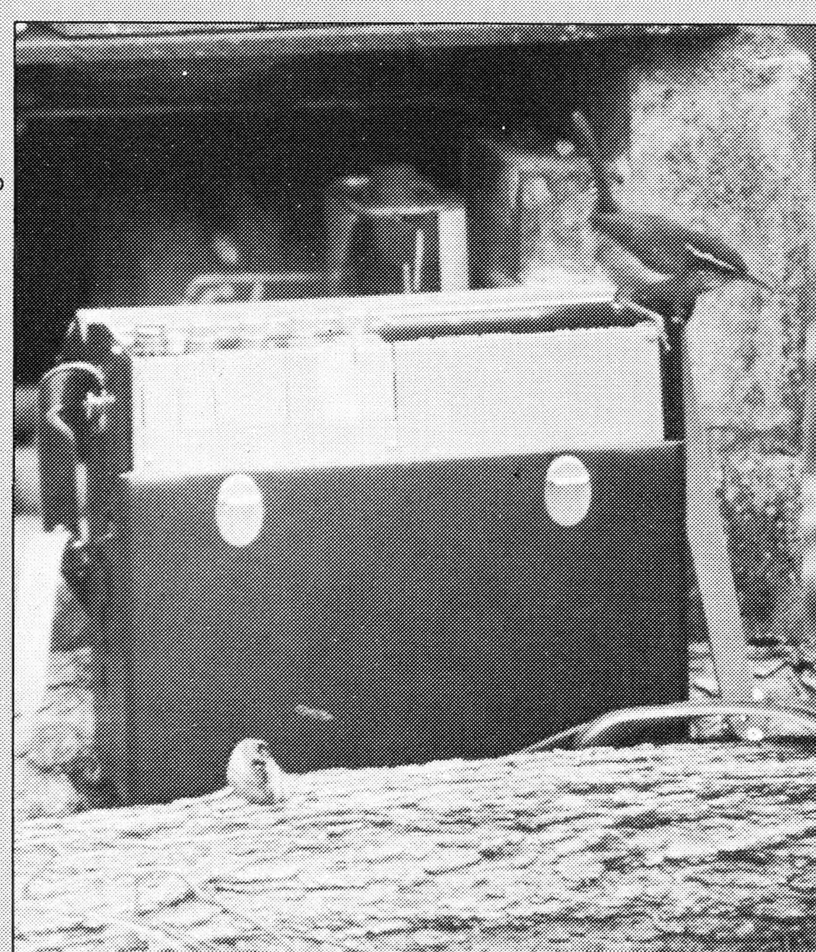
The beautiful, often boisterous songs of birds are symbolic of animal communication, and bird song has not been neglected in DZR. Historically, the scientific study of communication began with the question, "Why do birds sing?" Decades later debate over the function of bird song still rages, stimulated in part by research on Carolina wrens by NZP ornithologist Gene Morton and his students and associates.

Male Carolina wrens have song repertoires a night club singer might envy—but other males are not entertained by their neighbors' virtuosity. As Morton puts it, "The song of another male is like the whistle of an incoming round." The avian "soldier" guarding his territory must decide whether the shot came from an invader who has already breached the line and must therefore be forcibly repelled, or from an enemy far enough away that he can be safely ignored while the hungry bird eats. The decision is crucial: A male who wastes too much time fighting phantoms could starve to death, which, of course, would suit his competitive neighbors just fine.

Carolina wrens judge distance, not by the song's loudness as people do, but by matching the incoming sound to one like it stored in the bird's memory. If the sound is "degraded" or fuzzy, the bird knows the singer is far away; if it is clear and undegraded, the singer is dangerously close. Morton thinks that males in species like Carolina wrens sing many different songs so they have an arsenal of weapons to confuse their neighbors with—to trick them into fighting phantoms. In self-defense, males have developed the capacity to remember every new song they hear, in a sort of avian equivalent of the arms race.

The songs of birds, so bright and cheery to our ears, help the singers attract mates and establish their territories. But song is a highly developed form of communication. What came before? What sounds form the basis of these complicated noises?

Long ago, in the evolutionary process, it appears that animals developed certain sounds to convey different moods. By looking at sonographs—two-dimensional pictures of sound that show its change in frequency over time—comparisons can be made between the sounds produced by different animals. What Morton has learned is that many bird and mammal species express their feelings through a common "vocabulary" of sounds.



Eugene Morton

Highly territorial, a male Carolina wren attacks a tape recorder playing the song of another male wren.

Morton's studies have shown that such animals make three basic vocal sounds that express three different moods: the low, harsh growl (anger), the high-pitched whine (fright, friendliness, or submission), and the abrupt bark (interest). The best example of these sounds are those made by a dog. As you walk along a residential street, a dog behind a fence may bark. If you approach the fence, the dog may bark faster and then growl. If you in turn growl back at the dog, it may then whine to show fear or appeasement.

While the chirp of a bird and the sharp bark of a dog (both "interest-sounds"), or the screech of a frightened monkey and the squeal of a mouse being carried off by a hawk, may *sound* very different to our ears, on sonographs these sound patterns appear to be strikingly similar. Even more remarkable, Morton found that when he played the repertoire of Carolina wren calls slowed to half-speed on a tape recorder, the various calls were indistinguishable from the barks, growls, and whines of a dog.

These three elements then are the building blocks of animals' vocal "language." But unlike the words of human conversation, this language tells us only about the animal's *mood*. Animals do not say "things," but rather vocalize feelings: Humans stand alone in their ability to talk.

Still, as the cliche goes, it's not what you say but how you say it; whether we're cooing to a baby or grunting a retort to the alarm clock's morning buzz, we instinctively match our tone of voice to fit the occasion. We have only to compare such tones to the flat, computer-generated speech of a video game or "talking" Coke machine to realize that our human language, sophisticated as it is, owes much of its power to the mood language of our animal ancestors.

Except among birds, monogamy is rare in the animal world. For most male animals, the road to evolutionary success is paved with many females.

eating mammals that live exclusively on the island of Madagascar. Detailed studies of tenrecs in the wild and in captivity revealed remarkable uniformity in their basic behavioral repertoires, although other adaptations are quite different.

For instance, some tenrecs have long, barbed quills like a porcupine, others have thick, blunt spines like a hedgehog, and still others have soft fur. Despite their varied "wardrobes," courtship and copulation in these tenrecs are nearly identical. There is a brief period of mutual nose-to-nose and nose-to-tail touching and sniffing before the male mounts the female, holds her by biting the scruff of her neck (quills or spines notwithstanding), and they copulate for between seven and 30 minutes.

After mating, males and females of all tenrec species go their separate ways, but how far they go differs. In the hedgehog-like tenrecs, males and females associate only to mate; in the nonspiny tenrecs, pairs may share the same home range; while in the barb-quilled tenrecs, males and females and young may share the same burrow—but in all species, only mothers take care of young.

Why does anyone, aside from another tenrec, care how a tenrec copulates? By describing the behavior of primitive mammals, scientists like Eisenberg have been able to draw a picture of the basic pattern of sexual interactions—a pattern that can be discerned to varying degrees in all mammalian species. Points of divergence from this pattern in other species then become obvious and require explanation. An Asian elephant or an elephant-shrew (two more species that have been studied by DZR scientists) doesn't seem to have much in common with a tenrec, but the courtship and copulatory behavior of all three species are remarkably similar. And where they are different, we see elegant examples of how evolution through natural selection shapes behavioral differences between species. For example, elephant-shrews copulate only for brief seconds because to copulate for long minutes as tenrecs do might fatally distract them from watching for predators.

Genetic Lottery

Another group of species—bush dogs, maned wolves, crab-eating foxes, dik-diks, yellow-backed duikers, golden-lion tamarins, and (again) elephant-shrews—has been studied by DZR scientists because, aside from their intrinsic interest as little-known exotics, all are monogamous. Except among birds, monogamy is rare in the animal world. For most male animals, the road to evolutionary success is paved with many females. The more females a male mates with, and leaves to raise his young alone, the greater his chances of winning in the genetic lottery of the next generation. Why then do the males of a few mammalian species flaunt this evolutionary rule, mate with only one female, and sometimes even help take care of the kids?

Comparative studies of monogamous mammals by Devra Kleiman and her students and associates demonstrated that there are at least two answers to these questions—because there are two different kinds of monogamous lifestyles in mammals. Elephant-shrews and dik-diks, for example, are "facultatively monogamous." This basically means that males would be polygamous if given half a chance and that females wouldn't care if they were: A male's help in rearing young is not very important.

These males are monogamous be-

Eugene Maliniak

Jessie Cohen, NZP Graphics

Why monogamy? Reasons differ. Both parents must help raise tamarin young (left), while a dik-dik female will not tolerate a rival in her territory, which both sexes mark using scent glands under the eye (right).

In facultative monogamy, mates spend little time together, and frequently fight when they do meet.

cause the females will not tolerate other females living close by—food is too scarce to share—and any male's attempt to defend two or more females living far apart could well be futile. While a male chased an intruder away from one female, a third male might be mating with another of his females. Males have little choice but to stick with one female and hope to mate with her during every breeding cycle.

Even so, in facultative monogamy, mates spend little time together, and frequently fight when they do meet. Male and female share only their home range and in that area they keep their distance except to mate. Males tolerate their young, but offer little else in the way of parental care—perhaps because, despite a male's best efforts, the female's fidelity is far from certain and a male therefore has scant confidence that he really is the father of her young.

Cozy Families

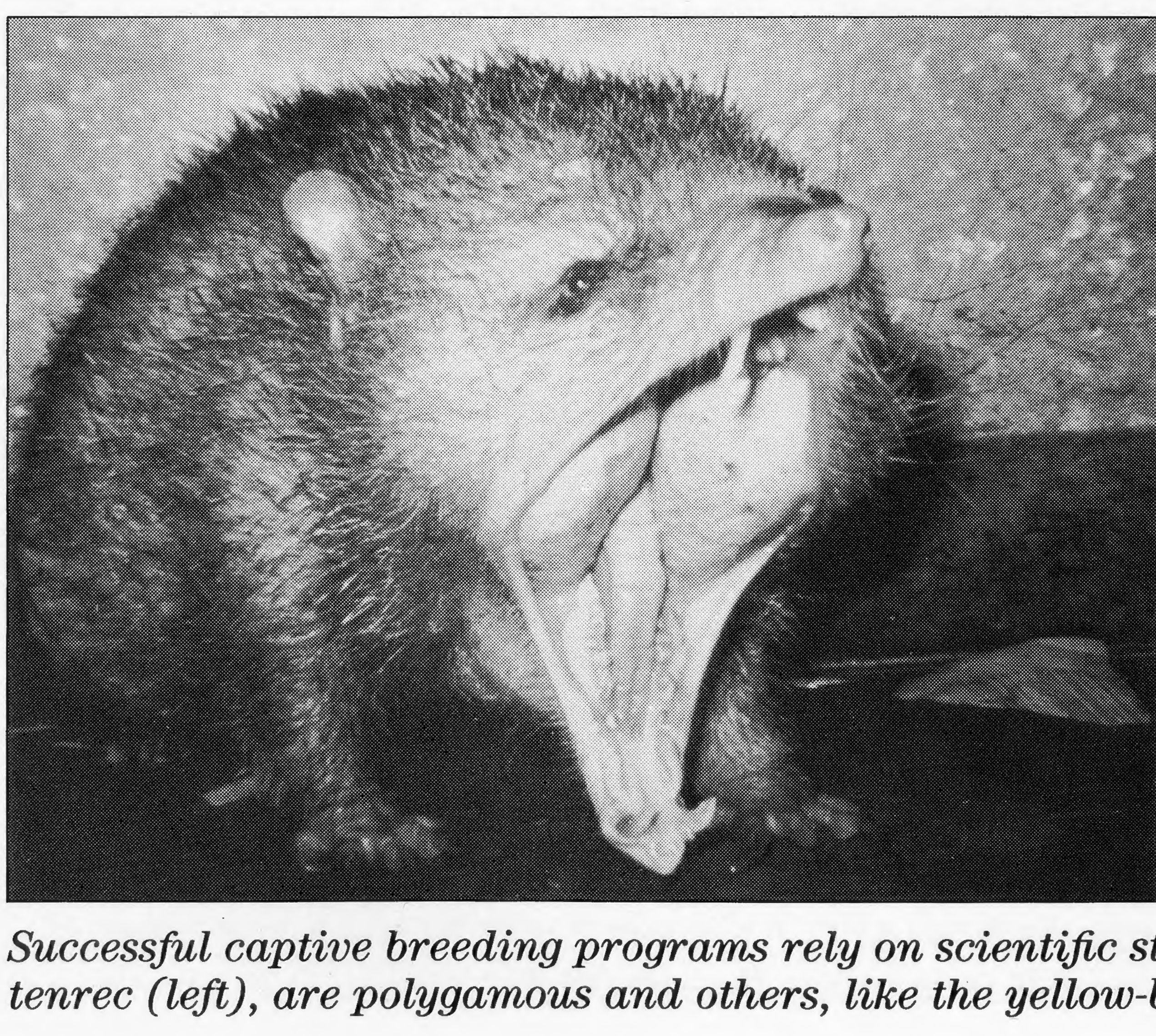
At the other extreme are species, like golden-lion tamarins and bush dogs, that have the kind of cozy family relationships the term monogamy implies. "Obligate monogamy" may have evolved because a male's help is essential in rearing young. When a female cannot raise young alone, males who mate with and then abandon a female to find other matings will end up with no progeny at all in the next generation. Thus the best genetic bet is for males to mate with one female and help her with the kids.

Of course, for this strategy to pay off, the kids must in fact *be* his. The very close bonds between male and female—they spend virtually all their time together—help to ensure this. A female who is never alone has little opportunity to mate with another male undetected. Both parents lavish care on their young, who, as they grow older, often assist in caring for younger siblings until they leave to form families of their own.

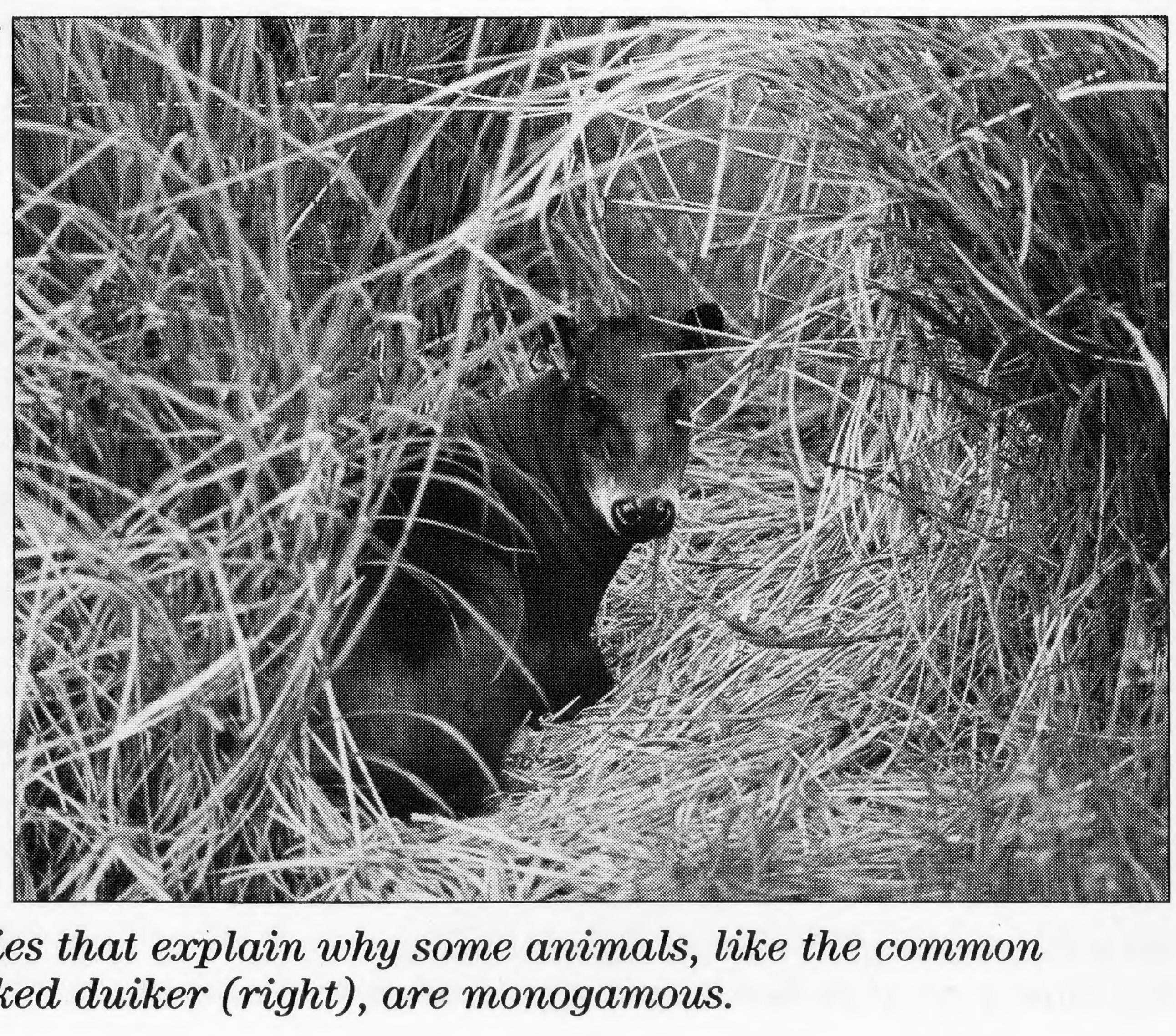
While few scientists care to draw parallels between people and other monogamous mammals, the latter have plenty in common with monogamous birds. Birds are often monogamous because it takes two parents to find enough food to satisfy the voracious appetites of their large broods. But males of many species, like the purple martins DZR ornithologist Eugene Morton studies, try to slip their monogamous bonds whenever they can. While a female purple martin is stuck sitting on eggs, her mate is shamelessly trying to copulate with females who are on the ground gathering straw and twigs to build nests. Although females are often guarded by their own mates, any unprotected female may have to fend off the forcible mating attempts of three or four males at once. Forced matings are seldom successful but their genetic rewards are great. A male who succeeds not only produces more young, but the female's mate unknowingly feeds them for him!

Stories about the lifestyles of animals can be easily told with the lightness of a gossip column. To students of animal behavior—be they DZR scientists or FONZ volunteer panda watchers—tracking down and documenting these stories is a thrilling pursuit, the occasional tedium and drudgery more than compensated for by the sheer fun of it. The goal of the research done by Zoo scientists is nonetheless profoundly serious: to understand how and why different species evolved in such exquisitely intricate adaptation to their social and physical world before man-induced changes in that world render the stories of too many species forever unknowable. □

Eugene Maliniak



Milton Tierney



Successful captive breeding programs rely on scientific studies that explain why some animals, like the common tenrec (left), are polygamous and others, like the yellow-backed duiker (right), are monogamous.

Nutrition

Diet Detectives

Olav Oftedal and Daryl Boness

Nutritional research by National Zoo scientists has made possible great advances in the development of healthful diets for a wide range of exotic animal species. Especially highly acclaimed are the DZR's nutritional studies of seals and sea lions, which have set the standards for care of pinniped species in zoos around the world. For example, the DZR nutrition lab has developed a substitute formula that can be used in the event that a sea lion gives birth and is unable to nurse her young. Behavioral and growth information gathered by DZR scientists is another important tool for keepers, who can now detect and correct problems at an early stage.

Seals and sea lions feed at sea but return to land to bear and nurse their pups. As is true for all mammals, the nursing period is vital for the healthy development of a young pup, yet costly to the mother who must continue to "eat for two," as she did during pregnancy, in order to produce milk.

Dr. Boness is an NZP Research Zoologist; Dr. Oftedal is the Zoo's Nutritionist.

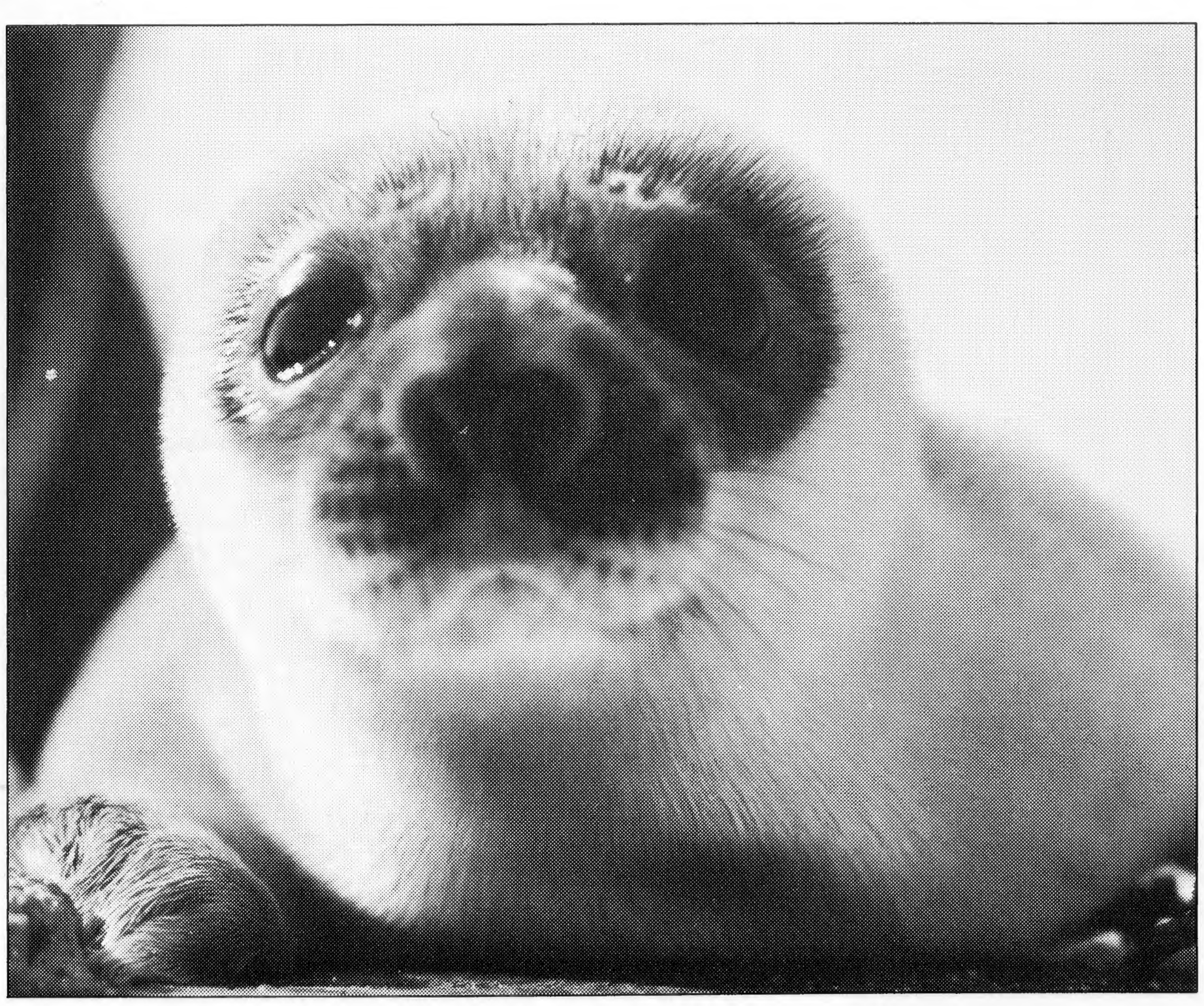
For lactating females of many mammal species, food may be no farther than a quick foray out of the den. But for seals and sea lions, the problem is far more complicated: Pups are nursed on land, or on floating ice pans, while the mothers' food may be far away at sea. This leaves a nursing mother quite literally between a rock and a hard place, for at any given time, she must choose between feeding herself and her pup.

Seals and sea lions, which give birth in habitats ranging from the ice-covered polar regions to the steaming tropics, have adapted to this unusual dilemma in very different ways. Seals have short lactation periods during which they typically stop feeding and stay with their pups. For example, gray seals fast throughout a 17-day lactation period; the females must therefore build up reserves of the nutrients needed for milk production before giving birth. By contrast, the California sea lion—the gray seal's next-door neighbor at the Zoo—nurses for a year or more, but females venture off to sea on periodic feeding trips. During these trips, which last for several days, pups wait on the beach in large "pods."

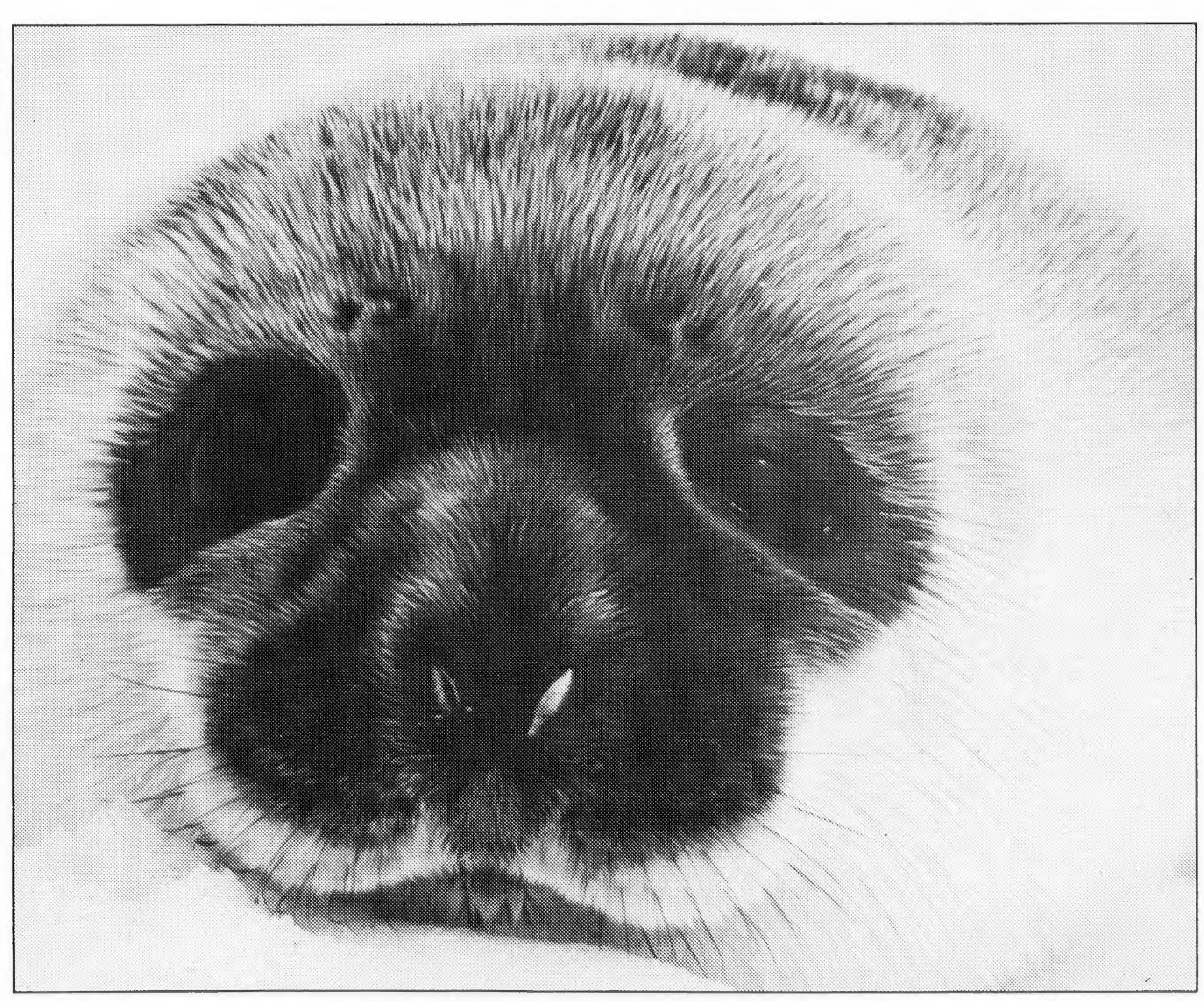
Why are the seal's and sea lion's strategies so different? National Zoo scientists have spent several years studying reproduction in different pinniped (the taxonomic order that includes seals, sea lions, and walruses) species to find out.

In 1981, we initiated a study of the physiology and behavior of California sea lions living off the southern coast of California. The long-term nature of this study has provided researchers with an unexpected opportunity to learn how food shortages affect maternal behavior and pup development. In 1983, unusually high sea temperatures, know as El Nino, drastically reduced the sea lions' normal food supply. During that year

Olav Oftedal



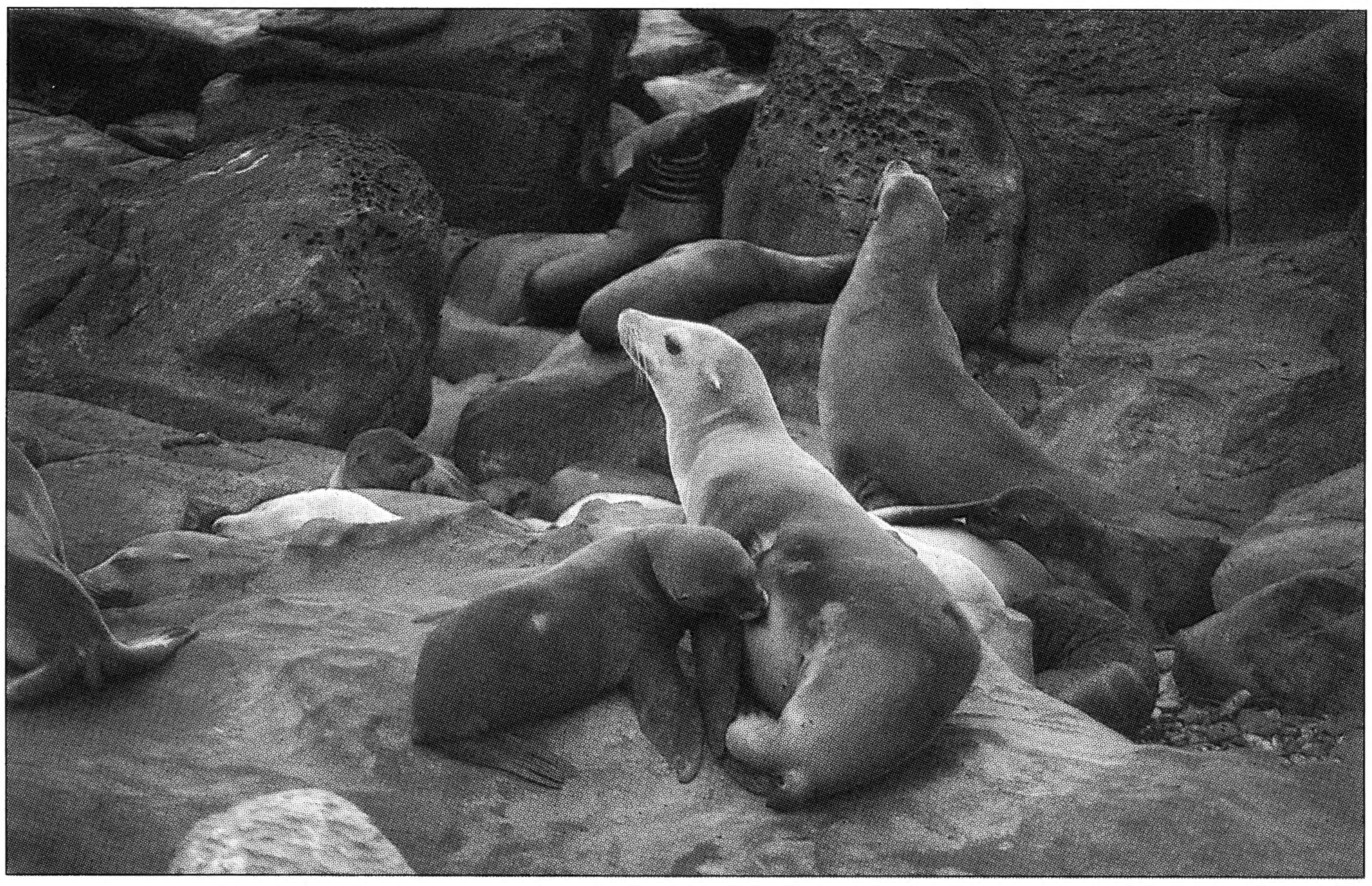
Olav Oftedal



Between its first (left) and fourth (right) days of life, a hooded seal pup will double its birth weight.

Jessie Cohen, NZP Graphics

Daryl Boness



Daryl Boness

and the next, mothers were forced to increase their time at sea in order to obtain enough food for themselves. As a result, pups suckled less, consumed less milk, grew poorly, and had a higher death rate.

In their patterns of behavior and physiology, seals, which breed on pack ice, are polar opposites to sea lions. Pack ice is highly unstable; storms can cause it to break up and drift several miles in a matter of hours. Harp seals are able to minimize the risk from ice instability because they nurse for less than two weeks; this was suspected to be the case in the ice-inhabiting hooded seal as well. Hoping to confirm the hooded seal's lactation period, we joined a 1984 research expedition organized by the Canadian government to study these animals off the coast of Labrador.

To everyone's amazement, it was discovered that hooded seals nurse for only *four days*! This is the shortest known nursing period for any mammal. Pups gain approximately 15 pounds each day, doubling their birth weight by the time they are weaned at four days old. Mother's milk alone is responsible for this incredible weight gain; it contains 60 percent fat, whereas homogenized milk from cows has only a four percent fat content. (The 60,000 calories a nursing hooded seal pup consumes *each day* would be enough to feed 25 to 30 people, or, depending on your point of view, the equivalent of 200 scoops of chocolate ice cream.)

Researchers are now trying to learn more about the sea lion's prolonged weaning process. By imitating the cycle of feeding and nursing that occurs in the wild, rather than allowing these activities to take place on a daily basis, the Zoo may be able to streamline the tricky process of weaning captive pups. □

Left: During the breeding season, male hooded seals inflate the bizarre-looking bladders for which they are named and create a racket by flapping them around. Center: This California sea lion pup will nurse for at least a year, waiting on the beach when its mother periodically returns to sea. Top: Sea lion pups at the National Zoo benefit from DZR studies of their wild counterparts.

The DZR Animal Collection

Zoo Within a Zoo

Devra Kleiman

As you enter the basement of the National Zoo's Hospital/Research building, a variety of sights, sounds, and smells greets you. This sensory extravaganza is produced by one of the most unusual animal collections in the world. Although off-exhibit to the general public, it is a treasure trove to the inquiring scientist.

For the past 20 years, the Zoo's Department of Zoological Research (DZR) has hosted approximately 130 species in an effort to learn as much as possible about these animals' basic biology and natural behavior. To do this, we provide each species with the environmental conditions it needs to behave as it would in the wild. The result is a hodge-podge of enclosure types that look chaotic to the casual visitor but actually result from a careful evaluation of each animal's requirements.

Our first goal with any new species is successful reproduction and the development of a self-sustaining captive population. We study the biology and behavior of breeding animals to help us create conditions that will lead to normal life history patterns among captive animals. We have frequently developed solutions to problems of maintaining particularly sensitive species in zoos and we have shared these findings with colleagues, thus helping to initiate major colonies at other sites. For example, DZR developed and refined the techniques for breeding golden lion tamarins, and this has led to our involvement in an international captive breeding program and the reintroduction of this species in Brazil.

Equally impressive, although less publicized, are our breeding programs for elephant-shrews, short-tailed opossums, and Western tarsiers. None of these species had previously bred successfully in captivity, despite intensive efforts. In each case, we gathered the existing life history information, combined it with our own observations, a few educated guesses, and some pure luck, and were able to devise the proper "recipes" for maintenance and reproduction. In the case of the elephant-shrew, the recipe was one part diet, two parts enclosure; we had to develop an enclosure to suit this monogamous but basically asocial species. The recipe reads: Put only one male and one female together, but be sure they can easily avoid seeing

(continued on p. 14)

Jessie Cohen, NZP Graphics

Two-toed sloth (*Choloepus didactylus*)

C. Wemmer

Malagasy civet (*Fossa fossa*)

Jessie Cohen, NZP Graphics

Sugar glider (*Petaurus breviceps*)

Eugene Maliniak

Pacarana (*Dinomys branickii*)

Frank Kohn

Kowari (*Dasyuroides byrnei*)

Eugene Maliniak

Western tarsier (*Tarsius bancanus*)

PAWPRINTS

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Zoo Scientists

If you have a pet, you know that it needs a good, clean home and a special kind of food. Zoo animals get special care, too, but it's often hard to know exactly what their needs are. How do you find out what a Malayan tapir eats or what kind of enclosure is best for a golden lion tamarin?

Scientists study the animals at the Zoo and in the wild so they can answer questions like these. Some animals eat just one thing in the wild—like the three-toed sloth, which eats only certain kinds of leaves. Feeding an animal the wrong thing can be harmful, so Zoo scientists study how different foods affect an animal and then develop just the right menu for it.

Finding out more about an animal's home in the wild is also important. Some animals, like tamarins, live in moist forests with lots of leafy plants. Others, like elephant-shrews, live in dry, sandy areas with brushy plants. Learning these details means that an animal's enclosure at the Zoo can be made more like its home in the wild.

For Zoo animals to live close to the way they live in the wild, scientists must also know how they act with others of their kind. Golden lion tamarins live in groups, for example, while giant pandas live alone. At the Zoo, different kinds of animals are kept alone, in pairs, or in groups, depending on how they would live in the wild.

When an animal's life in the Zoo resembles its life in the wild, it is more likely to reproduce. That is one way the scientists' efforts have helped many animals have babies at the Zoo.

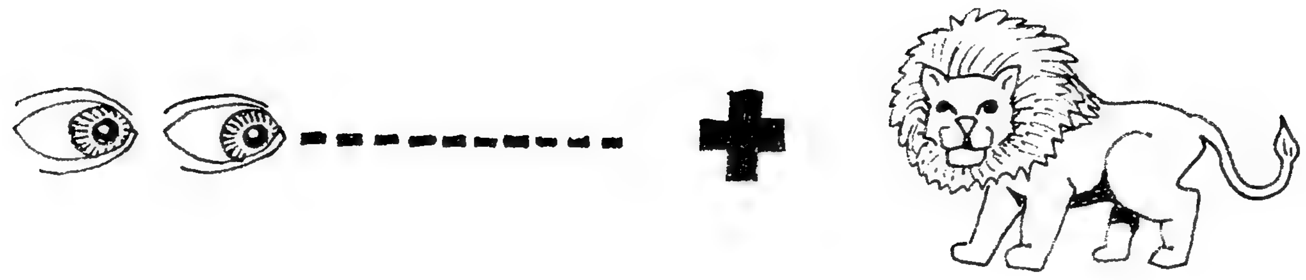
The scientists also help animals in the wild by finding out what foods and habitats different kinds of creatures depend on. Scientists and other people can then work together to take care of these important foods and habitats so the animals can use them for a long, long time.

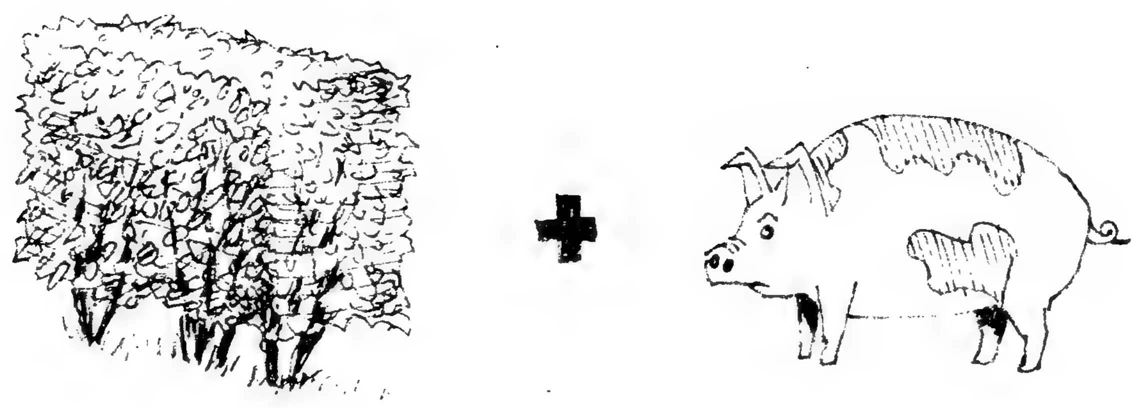
So, the next time you visit the Zoo and see a panda eating bamboo or the spectacled bear cubs playing on the logs in their enclosure, think about all the work the Zoo's scientists are doing to help us take the best possible care of animals in the Zoo and around the world.

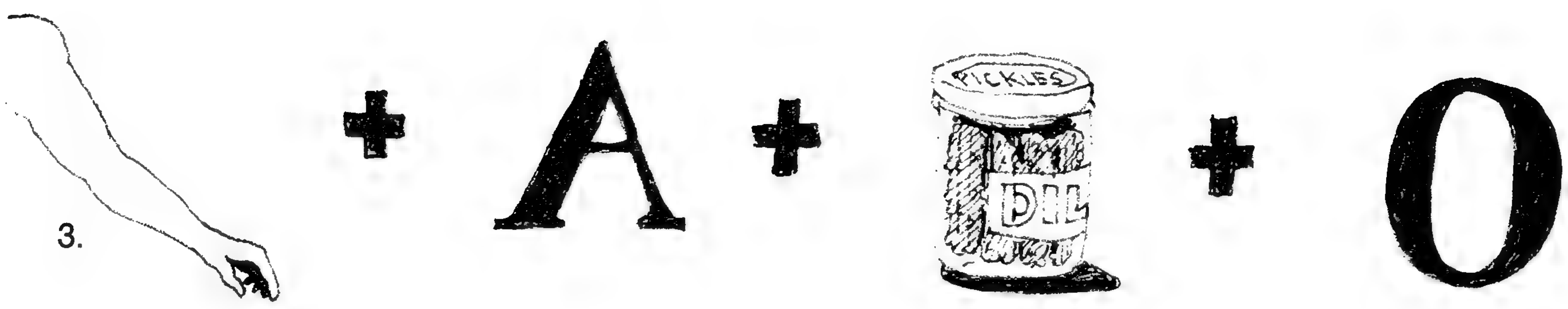
—*Margaret Parker*

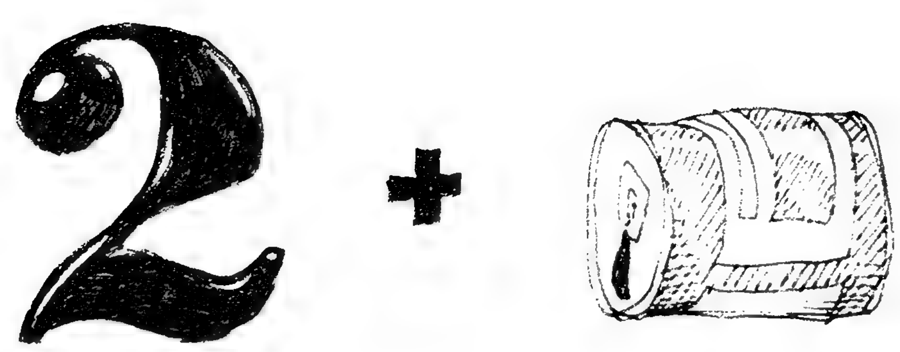
National Zoo scientists study the lives of these streaked tenrecs and other unusual animals.

◀Zoo Rebus

1. 

2. 

3. 

4. 

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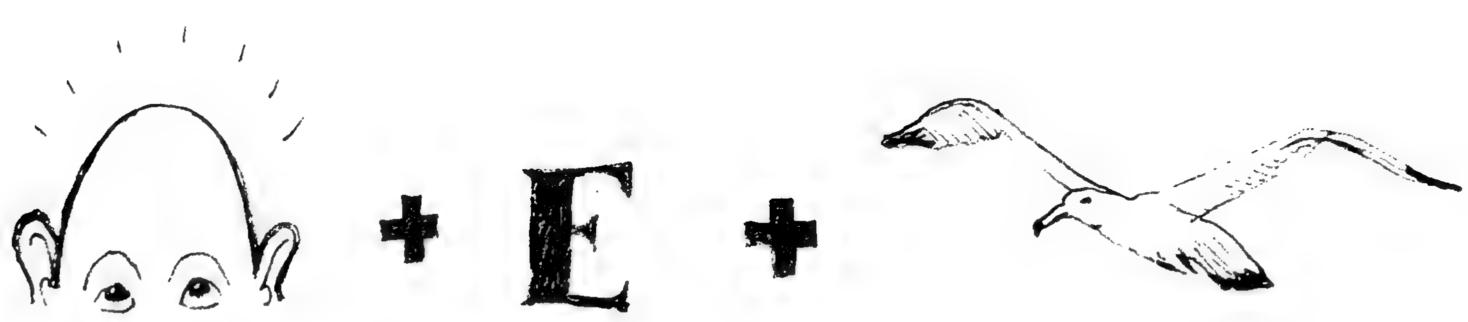
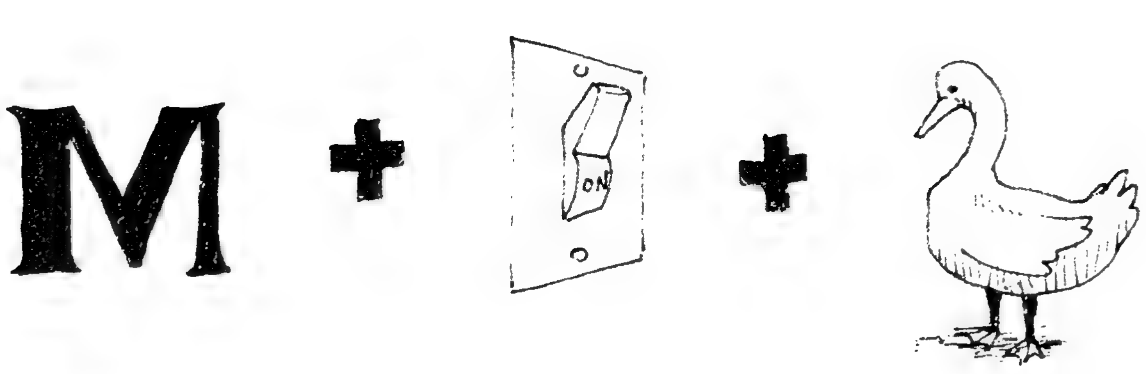
6. 

7. 

Can you solve these animal rebus riddles? (Answers are on last page.)

1. (Example. Answer: Sea lion)

2. ____________________

3. ____________________

4. ____________________

5. ____________________

6. ____________________

7. ____________________

Christopher Hoge

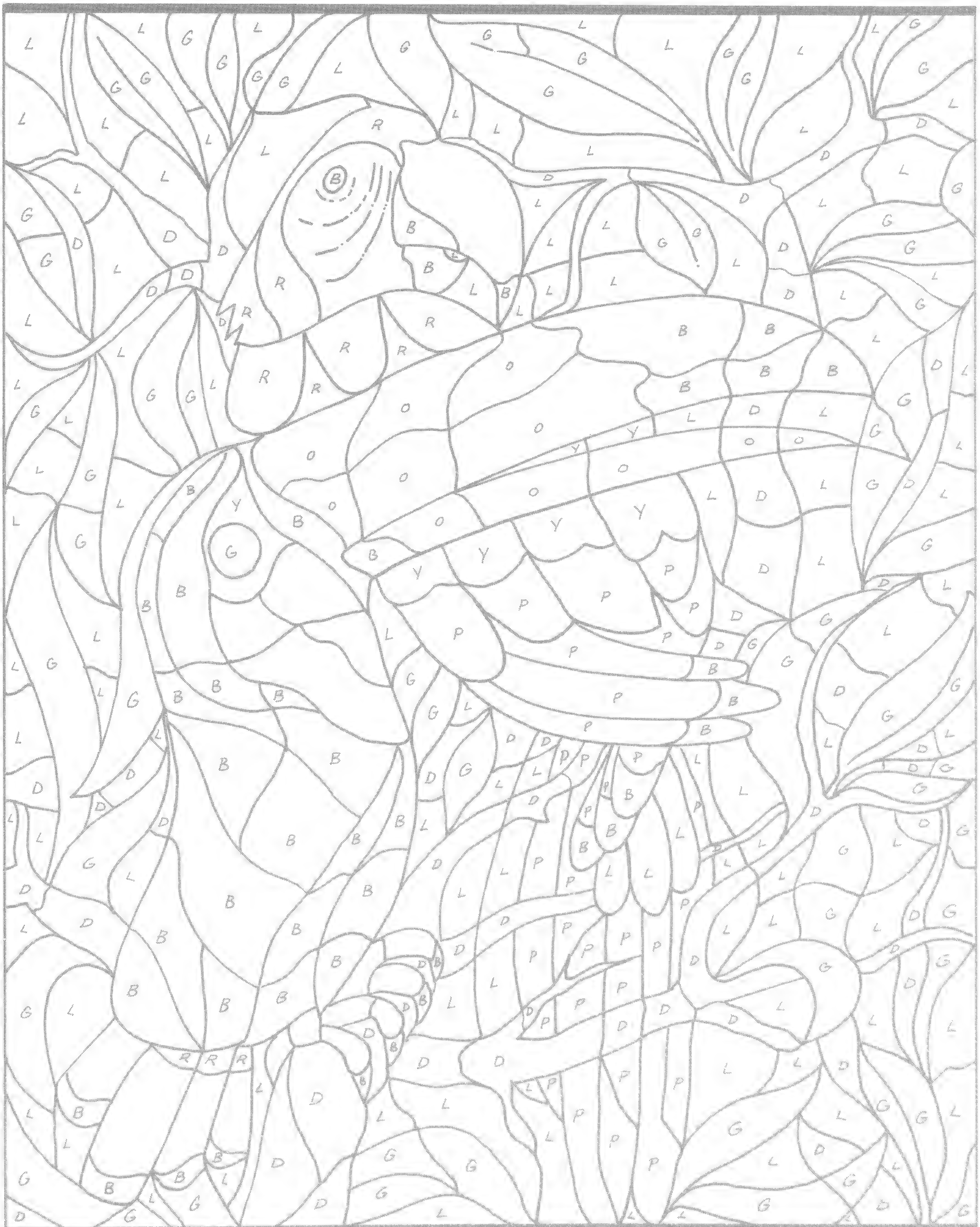
Tropical Treetop ▶

Who can find the macaw and toucan?

You can! Color in the shapes according to this color scheme:

B = Black
G = Green
D = Dark Green
L = Light Blue
O = Orange
P = Purple
R = Red
Y = Yellow

(Shapes with no letter are white.)



Things to do at the Zoo

Welcome Pangur Ban, a two-year old white tiger from the Omaha, Nebraska zoo. Also new to Lion-Tiger Hill is a Sumatran tiger, Riau, which is smaller and more deeply colored than its mainland tiger cousins.

Visit Zoo babies. Animals born over the summer include bobcats, a giraffe, red pandas, a bongo, a spider monkey, a lion-tailed macaque, and a golden-headed lion tamarin, the first ever born in North America.

Discover ZooArk, a new exhibit that shows how zoos are helping to save the world's wildlife. Free maps of the six-part exhibit are available in the Education Building.

Enjoy these special Sunday Afternoons at the National Zoo (call 673-4717 for information about free tickets):

Make a mask and learn about animal folklore during "A Celebration of Animals." November 23.

Watch *Never Cry Wolf*, a holiday film about the life of wild wolves in Alaska and one man who studies them. December 14.

Zoo Rebus Solution; 1. Sea lion, 2. Hedgehog, 3. Armadillo, 4. Toucan, 5. Crowned crane, 6. Bald eagle, 7. Mongoose

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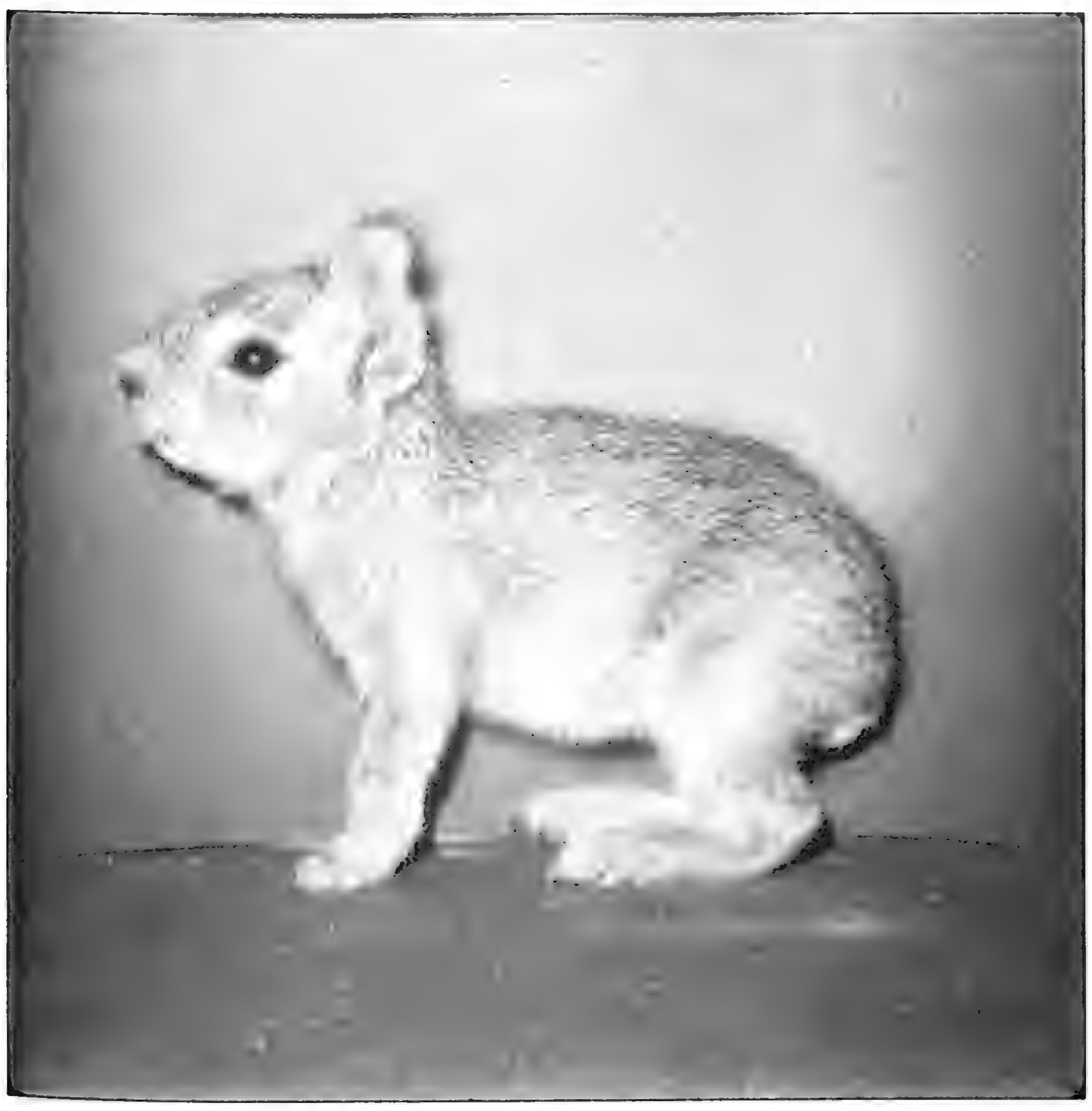
Jessie Cohen, NZP Graphics

Born last August, this golden-headed lion tamarin lives with its parents in the Small Mammal House.

Jessie Cohen, NZP Graphics

The National Zoo's polar bears have moved north! The Zoo staff decided that the polar bears' outdoor exhibit was too hot and sunny for the Arctic animals, who have been sent on to new, cooler homes at zoos in Detroit and Chicago. But bear fans need not say goodbye—more polar bears are as close as the Baltimore Zoo (301-366-5466).

Ring-tail possum (*Pseudocheirus peregrinus*)



Lesser mara (*Dolichotis salinicola*)

Paca (*Agouti paca*)

Jessie Cohen, NZP Graphics

Short bare-tailed opossum (*Monodelphis domestica*)

C. Warner

Woolly opossum (*Caluromys lanatus*)

Our first tarsier infant was so prized that literally no one, including me, was permitted to see it until it was weaned.

(from p. 11)
and interacting with each other, wait approximately three months and—*voilà*, baby elephant shrews!

Institutions throughout the United States and abroad now have animal colonies derived from the DZR collection, and we have published a great variety of papers on animal care, management, biology, and behavior. Our many awards from the American Association of Zoological Parks and Aquariums include recognition of our breeding successes with rock cavies, punares, rufous elephant-shrews, leaf-nosed bats, and short-tailed opossums.

The major part of DZR's animal collection is usually devoted to an animal group whose evolution interests us. Indeed, one of my greatest pleasures and privileges has been the opportunity to observe and compare the life history and behavior of a variety of closely related animals. My studies of the evolution of monogamous mating systems in mammals would not have been possible without colonies of several monogamous species, like the golden lion tamarins, elephant-shrews, acouchis, and titi monkeys. Steve Thompson's comparative studies of the energetics of reproduction in marsupials and placental mammals also required a dynamic and productive animal collection.

The Department's interest in comparative behavior drives our cycles of species acquisition; we continue to bring in unstudied species and encourage our colleagues to work with our most recent successes. Over the years, the species of our diverse collection have come from what sometimes sound to be the very ends of the earth—and some very odd corners of the animal kingdom. We started with a set of Madagascan insectivores, the primitive tenrecs, moved to the dasyurid marsupials (the narrow-footed marsupial "mice," Tasmanian devil, tiger cat) and the caviomorph rodents (acouchis, degus, spiny rats, pacas, maras, porcupines, and cavies), and eventually returned to marsupials, but this time to those of South America (yapoks, woolly opossums, four-eyed opossums, monito del monte). And in between, we have looked at South American fruit bats, chestnut-sided warblers, Carolina wrens, several hamster species, and sloths.

With this unusual set of animals and our successful breeding programs, we have been lucky to share in some unique events. Our first tarsier infant was so prized that literally no one, including me, was permitted to see it until it was weaned. But I did get my first view of courtship in the pacarana (Branick's giant rat). Male courtship in related species involves frequent approaches and withdrawals, tailwagging, trembling of the forelimbs, and rhythmical high-pitched squeaking. Periodically, the male will stand upright and urinate over the female. Occasionally, he appears to become so frustrated from his advances being ignored, that he suddenly leaps into the air and begins racing violently around the enclosure while squeaking loudly. They look pretty silly, but the pacarana had a further surprise in store for me. Late one afternoon, I heard some loud noises coming from the pacarana cage and rushed over to find the 50-pound male "singing" to the female while lumbering around her with nearly his whole hulking body trembling. An uninformed observer could easily have thought he was near death, but he was only courting. The female acted oblivious and calmly ate her ear of corn!

I was enthralled. Animal watching, as any zoo visitor knows, is endlessly fascinating, and our zoo within the Zoo continues to produce many rare and exciting moments. □

Eugene Maliniak

Prehensile-tailed porcupine (*Coendou prehensilis*)

Eugene Maliniak

Hedgehog tenrec (*Setifer setosus*)

Long-Term Research

Close Encounters

Jake Page

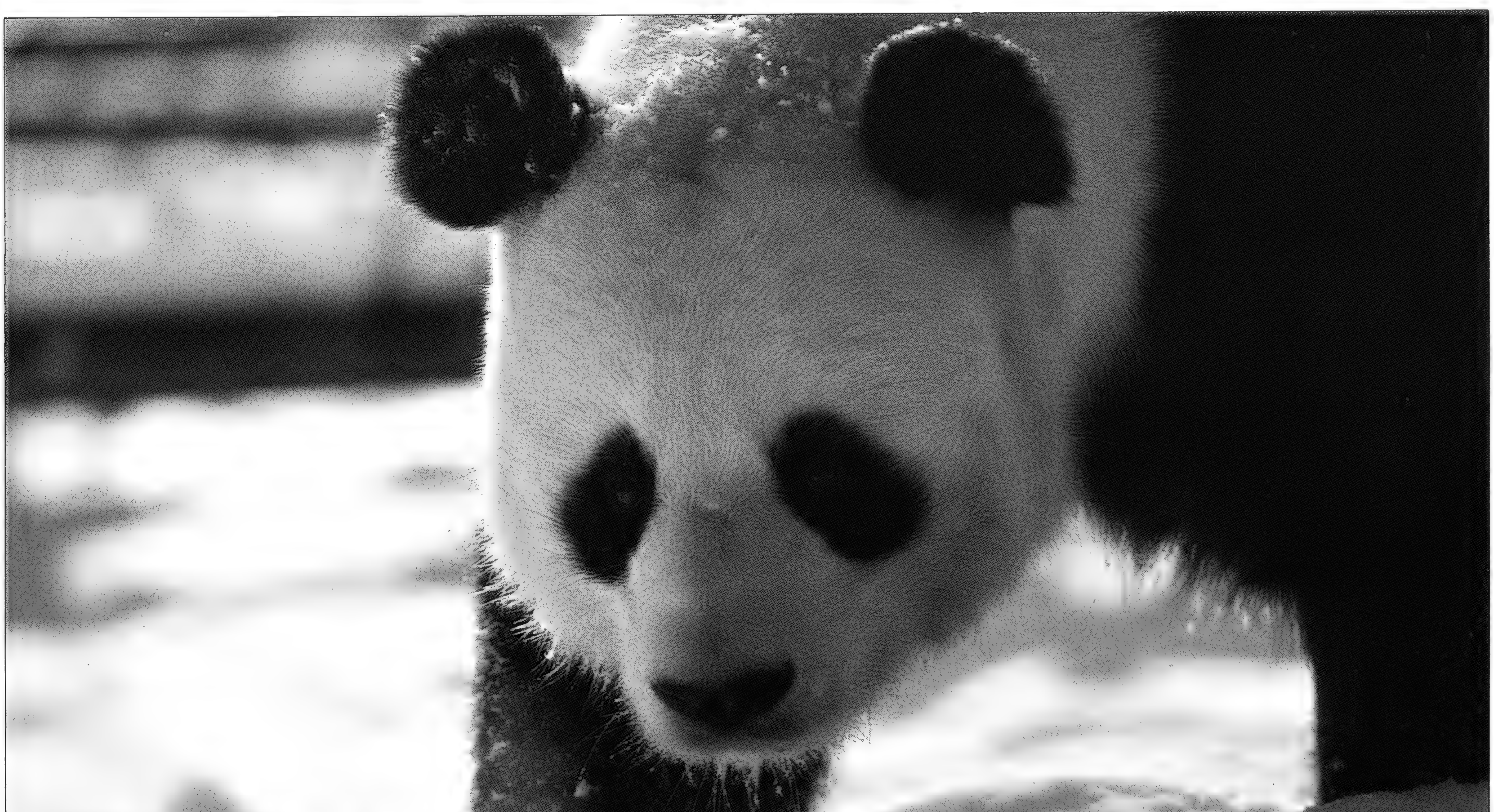
What could be more straightforward? You have an abundance of a certain kind of monkey in the nation's zoos but in the coastal rain forests of Brazil where it belongs there aren't enough. So send some down, right? They are, after all, little biological machines—operated by hundreds of generations of DNA strands, the original golden lion tamarin textbook. So what if the zoo group hasn't seen a rain forest for a few generations? Genes don't forget.

Jake Page is a freelance writer whose book on the National Zoo will soon be published by Smithsonian Books.

It isn't that simple of course. It took many years of observing both captive and wild tamarins, careful biomedical intervention, ecological studies of tamarin habitat and social behavior, and exhaustive genealogical record-keeping, not to mention some tamarin "Outward Bound" training programs before researchers at the National Zoo and in Brazil were able to release a couple of bands of these wondrous creatures into their original home.

Releasing captive-bred primates into the wild had been tried before—and with a notable lack of success. It worked with the Zoo-trained golden lion tamarins, however, because researchers had long made a point of learning everything possible about what we might call tamarin "culture." Each animal species is unique, and each has its own way of going about the business of living. But to know one member of a species is not to know them all, for individual animals may differ in important ways, such as in their ability to adapt to a

Jessie Cohen, NZP Graphics



Hundreds of FONZ volunteers have spent thousands of hours closely observing Ling-Ling.

new environment. Even among birds of one species, National Zoo ornithologist Eugene Morton has found, some individuals are simply going to do a better job than others if they are put in a new habitat.

So it is, evidently, with pandas. Giant pandas in some other zoos have produced young successfully but, alas, not the pair at the National Zoo. Just why that is, no one really knows, but while Ling-Ling and Hsing-Hsing have produced no viable offspring, they have yielded what may in the long run be of greater significance. For, since the pandas' arrival in 1972, they have been perhaps the best and most thoroughly observed zoo animals in history. More is known now about the details of the panda reproductive cycle than could ever have been imagined B.L.L. (Before Ling-Ling)—even down to the molecular level. And this information, widely shared with other zoos, may well prove more important than one more panda cub in the long process of panda conservation. (This body of knowledge is a legacy created in considerable part, of course, by hundreds of FONZ volunteers.)

Being connected with pandas at the National Zoo is not easy, as DZR Collection Manager Miles Roberts has pointed out. Those who work with giant pandas must always be explaining the details of "celebrity sex life," but those who, under Roberts' guidance, work with red pandas often find themselves explaining just what animal they are talking about. It is only within the last decade that people have stopped referring to these enticing creatures as "lesser" pandas.

In fact, it was only recently determined just what red or giant pandas are . . . or at least where they fit into the animal kingdom. Arguments had long raged (in admittedly exclusive circles) about panda classification until Steve O'Brien of the National Institutes of Health and a research associate of the Zoo performed sophisticated genetic analyses and found that red pandas are closely allied with raccoons while giant pandas belong more in the realm of the bears. Both are maverick carnivores—they largely gave up meat long ago in favor of bamboo—and through what biologists term convergent evolution, developed certain anatomical similarities such as wrist bones modified to be "thumbs" for clutching stalks of bamboo.

Such a finding is the result of "pure" research—a healthy curiosity about other lives and, in fact, a kind of courtesy paid to one's fellows. But research chiefly motivated by curiosity can—and usually does—have a practical pay-off.

The red panda, for example, has recently become the subject of an intense captive breeding effort under a Species Survival Plan (SSP) coordinated by Roberts. But before an inter-zoo breeding plan could get under-way, Roberts' already complex undertaking grew more complicated still. In his years of looking out for the National Zoo's red pandas, Roberts had concluded that there were no subspecies; museum specimens

Smithsonian Institution

Ever since 1972, when the National Zoo's first mother-reared cubs were born, red pandas have been a focus of intensive, long-term research by DZR scientists.

seemed to show that those found in the mountainous habitat of China were the same as those living further west in the Himalayas.

Nevertheless, it seemed best to check. Blood samples collected from the red pandas living in American zoos were analyzed by Ned Gentz of the University of New Mexico, who discovered significant genetic differences between the populations at either end of their natural range: in other words, two subspecies. This finding was factored into the SSP, calling for a far more elaborate genealogical monitoring of the animals. More hard work but, as Roberts says, "Without the analysis we would have been groping in the dark." Now zoo managers know they are dealing with two distinct populations as they take over much of the strategy of plotting future red pandadom from this point in the animal's evolution. This is an awesome responsibility, one made necessary in large part by habitat destruction, as is the case with so many species of wildlife.

Red panda habitat, seen on a map, seems respectably large—a long strip of temperate Himalayan forest. But, in fact, as Roberts found out when he traveled to Nepal in 1979 to look for these animals, their range is really a long narrow ribbon running the length of the mountain chain. Below 2200 meters, it is too wet and too hot for red pandas; above 4500 meters, there's no bamboo.

But as the human population grows in these lands, people tend to move up into the rugged, nearly vertical territory of the red pandas, transforming the mountainsides into terraced plots for agriculture. Higher up, deforestation for fuel wood and building materials has led to the erosion of the relatively rich hills of the bamboo forest. The net result is that red panda habitat is no longer even a ribbon but, more and more, consists of many separate strips along the former range . . . in effect, islands in which small panda populations, now isolated, are subject to those twin ills of inbreeding: infant mortality and reduced fecundity.

There are things that are difficult, sometimes impossible, to learn in the field, and it is in such situations that long-term studies of zoo populations become especially helpful. Over the years, Roberts and his colleagues at Front Royal and in the Department of Mammalogy have put together an intimate picture of the red panda's reproductive cycle. It is a system that has worked perfectly well for the animal for thousands and thousands of years, providing the "right" number of young red pandas to maintain the species in its narrow and specialized world. But it is a system that is unlikely to respond well to sudden changes.

Mating occurs in winter, between January and March, and the gestation period of 135 days is remarkably long for an animal of this size. The one or two cubs nurse for two months, again a long time in such affairs. If the cubs are lost, the mother must wait until the following year to have another litter. Given the relatively harsh exi-

Jessie Cohen, NZP Graphics

Learning the individual characteristics of animals most likely to survive was an important part of the golden lion tamarin program, since it helped determine which animals would be returned to Brazil.

gencies of life, a female red panda may normally—over about five years of breeding life—produce some three or four young that reach reproductive age—half male and half female. Thus a female is likely only to replace herself in her lifetime, a reasonable equilibrium for an animal in a restricted but constant ecosystem, but bad news if the status quo is under pressure. Any number of subtle events can lead to population decline and this is precisely what Roberts assumes is happening in the wild. (In zoos, reproductive success has recently risen to the point of replacing the old members, but it too could decline if it is not properly managed.)

Meanwhile other studies of red panda anatomy and physiology are adding detail to this picture of a fragile species poised on a dangerous edge.

Ted Grand, a functional anatomist in the Department of Zoological Research, has found in post-mortem examinations that the red panda has the lowest known proportion of muscle to body weight of any known carnivore. In addition, the skeleton permits an unusual amount of lateral movement of the legs. Both of these are adaptations to the animal's largely arboreal habitat—an evolutionary veering towards a primate mode.

At the same time, Brian McNab of the University of Florida has looked in on the energetics of some of the Zoo's red pandas, finding that they have a remarkably low metabolic rate—perhaps the result of the low proportion of muscle, but an adaptation that also allows the animal to subsist on a low-energy diet of such food as bamboo. All of this probably determines the great length of the gestation period and the low reproductive and growth rates among these animals.

All in all, these studies show a delicate situation—though not dispiritingly so. At least Roberts and his colleagues are *not* groping in the dark when it comes to red pandas. Instead, as Roberts puts it, what might "appear as a bunch of unconnected projects has eventually linked up in an exciting synergism." There is an urgent need these days for what might be termed salvage zoology on behalf of many, many wild creatures, and without the kind of intimate knowledge collected over the years by researchers at the Zoo and their colleagues in other institutions, such efforts would hold out little hope for the future. So, three cheers for curiosity. □

The Genetic Management of Captive Populations

Whether they live in a zoo or an isolated "island" of wild habitat, small populations of animals have difficulty surviving for long periods of time. They are vulnerable not only to chance events, like epidemics or natural disasters, but also to the equally devastating effects of inbreeding.

As long as genetic variation is preserved, a population remains genetically flexible, able to adapt to changing conditions. In captivity, this is particularly important for species, like the golden lion tamarin, that may be reintroduced into the wild. Unfortunately, genetic diversity rapidly disappears in small populations as inbreeding (the breeding of two related individuals) and genetic drift (the random loss of genes from one generation to the next) reduce the genetic diversity of each successive generation.

In addition to the long-term hazards posed by a loss of genetic diversity, the short term consequences of inbreeding can be severe. DZR studies on more than 40 mammal species showed that in all but three populations, the mortality rate of inbred young averaged about 15 percent higher than that of non-inbred young. The effect of this elevated mortality on a small inbred group may be enough to drive the population to extinction.

The first crucial step in the genetic management of small captive populations is compiling the required pedigrees. Then, using these "family trees" to minimize inbreeding, matches are made between individuals that are as distantly related as possible, while breeding as many different individuals in the population as possible.

Assisting in this sometimes complex process are sophisticated computer programs which determine the relationships between all living members of a species in captivity. When pedigree information is not available, biochemical analyses are used to help determine relationships. For example, examining genetic markers from blood or animal tissues can yield important clues to the identity of an unknown sire. In addition, the laboratory technique of electrophoresis allows us to monitor changes and fluctuations in levels of genetic variation in different populations through time. It is an important tool for evaluating the effectiveness of our efforts to maintain genetic diversity while building captive populations.

The genetic management of captive populations is a rapidly growing field, and zoo managers have become increasingly reliant on the expertise of outside scientists in such diverse fields as human and population genetics, biochemistry, demography, statistics, and population biology. We hope that with the help of this impressive line-up, we will continue to increase the long-term survival of our captive populations of endangered species.

—Jon Ballou
Population Manager

Field Research

The Zoo Afield

John Eisenberg and Devra Kleiman

Typically several years in duration, field projects allow researchers to study little-known species within the context of their natural environments. The information they gather, including observations of an animal's diet, territorial needs, mating habits, family structure, and role within its plant and animal community, not only increases basic scientific knowledge, but is often key to the management of that species in captivity. In many cases, such studies also lay the groundwork for the development of large-scale conservation plans to support a variety of animals and their habitats in the wild. From its earliest days, the Department of Zoological Research has conducted a host of field studies in Central and South America, North America, Asia, and Africa.

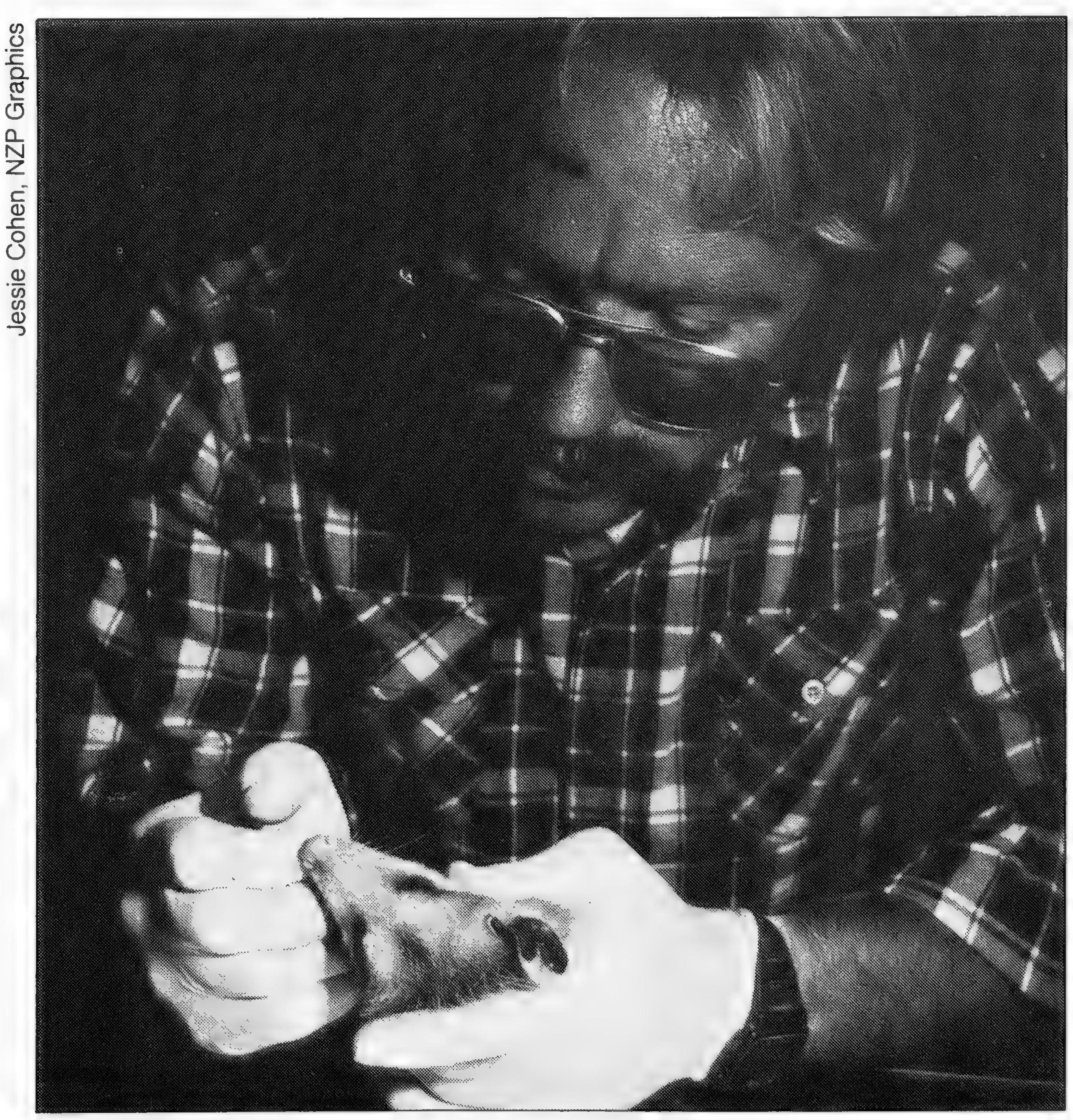
Founder and former director of the Zoo's Department of Zoological Research, Dr. Eisenberg is now the Ordway Professor of Ecosystems Conservation at the Florida State Museum. Dr. Kleiman has been DZR director since 1979.

Panama. The National Zoo's role in Panamanian research began in 1965 with Eisenberg's study of the red spider monkey and a subsequent study of Geoffroy's marmoset by Nancy Muckenhirn. Nicholas Smythe also undertook a very successful study of the behavior and ecology of the agouti and the paca, two large rodents on Barro Colorado Island, the Smithsonian Institution's tropical research reserve. Smythe's work was completed in 1969.

Research in Panama resumed in 1970 with Eisenberg's initiation of the sloth project. Gene Montgomery and Melvin Sunquist carried out the extensive field work, which provided the first information on the activity cycles, diet, and social behavior of two- and three-toed sloths. This was a pioneering study in that it involved the use of radio telemetry to record the position of sloths in the forest canopy. The assistance of Zoo veterinarian Mitchell Bush, who participated in several aspects of Panamanian research, was instrumental to our work on sloths. Among the discoveries was the manner in which sloth mothers donate territory to off-

Daryl Boness

Jessie Cohen, NZP Graphics



Travelling to the Arctic circle, DZR researchers studied seals in their natural habitat (left); at the Zoo's Conservation Center in Virginia, they studied opossums and other local fauna (right).

Social Evolution Among Wild Macaques

The evergreen forest of Polonnaruwa, Sri Lanka, has been a major site of primate research since the 1960s. Home to two species of leaf-eating monkeys (langurs), as well as the toque macaque and the nocturnal slender loris, it is little wonder that the area has also become the natural habitat of that most curious primate "breed," the field researcher.

Of the area's primates, the toque macaque has been the most intensively studied by several investigators, including my wife Anne, my Sri Lankan students, and me. Easily distinguished by such varied natural markings as skin pigmentation and characteristic "hairdos," the forest's approximately 500 macaques, which live in 22 different social groups, have been individually identified, enabling us to trace the unique behavioral and demographic history (birth, death, immigration, and emigration) of each one since either 1968 or 1975.

Through nearly two decades of research, we have sought to measure, for the first time, how such factors as social behavior, kinship, and environmental change influence the fitness of individual animals. (Fitness is an individual's probability of surviving and of raising offspring that can in turn reproduce.) Such concrete measures allow us to test theories concerning the evolution of social behavior. For example, compare a tendency to fight to the death in the face of strong aggression with the alternative tendency to avoid an escalation of conflict by acting submissively and so live to fight (and reproduce) another day. Following standard evolutionary logic, a tendency to fight to the death is not commonly seen in animals today because ancestors which behaved in such a manner left fewer descendants than those which settled conflicts more peaceably.

But such hypotheses, though logically sound, present a problem, for it is difficult to measure the relationship between a given behavior and individual fitness, and hence to examine that behavior's susceptibility to natural selection. Why? Because the effect of a behavior on an individual's fitness is not only likely to be subtle, but may well vary with different ecological and social conditions. This is especially true in monkeys, which have complex social relationships, long lifespans, and slow reproductive rates.

The Polonnaruwa studies are unique because they solve this problem by simultaneously studying the life histories of a great number of individuals over many years. Thus, at this point, we know the histories of more than 1,000 macaques that have lived (many having died) in an 18-year period. Such a large data sample allows us to measure the subtle effects of behavior on individual fitness, and the variations in these effects owing to an individual's age, kinship, group membership, and other characteristics. Theories of the evolution of social behavior, including the controversial hypotheses of kin and group selection, can thus be tested against lifetimes of practice. Long-term ecological and demographic data, which concern an entire population of primates, are also unique and invaluable in the formulation of general wildlife conservation practices.


Anne Baker

The ease with which toque macaques can be identified as individuals from their natural markings has allowed DZR researchers to trace the behavioral and demographic histories of animals such as adult male "Stumpy," shown here at the ripe old age of 16 to 19 years.

New discoveries about toque macaques have been an exciting byproduct of the socio-demographic studies. We found, for example, that they use "food calls" to communicate with their fellow group members about the location, quality, and quantity of food sources; such "semantic" signaling was once thought to be unique to humans. Also, detailed studies of mother-infant relationships have revealed that macaque mothers favor infant sons over daughters, and that males favor infants which they have probably sired.

The current and planned studies at Polonnaruwa are expanding in scope through collaboration with other scientists and institutions. For example, we will use blood proteins to define the genetic differences between individual macaques and their family lineages and groups. Furthermore, to obtain indices of differences in health, all macaques will be biomedically examined for parasites, viral and bacterial infections, immunology and tooth wear. Together such data will enable us to further refine our knowledge of the relationship between social behavior and its effect on life and death, and ultimately of the evolution of social living.

—Wolfgang Dittus
Research Associate

Madagascar field research permitted the National Zoo to exhibit a number of rare mammals that were imported from the island.

spring by moving to another area. Also, it was found that sloths have a unique elimination cycle: At intervals of three to four days, each sloth descends to the ground, digs a small hole at the base of the tree using its short, squat tail, and then defecates in the hole before climbing up into the canopy.

With its all-but-undisturbed forest housing a wealth of tropical species, Barro Colorado Island has played a central role in the working lives of countless students and researchers associated with the National Zoo.

More recently, studies have included an examination of antwren foraging behavior by Judy Gradwohl and an experimental analysis by Russell Greenberg of the development of foraging behavior by neotropical migrant warblers whose diets change dramatically when they migrate to Central America from the Northeastern United States where they are hatched.

Eugene Morton conducted preliminary studies reintroducing two bird species to Barro Colorado Island after they had become extinct on the Island. Additionally, his student Susan Farabaugh conducted a major study of the correlation between the characteristics of duetting and the strength and expression of the pair bond in several species of monogamous neotropical wrens.

Madagascar. Research in Madagascar was a cooperative effort between the National Zoo and Johns Hopkins University, where Edwin Gould, currently NZP Curator of Mammals, served on the faculty. Working as a team, Gould and Eisenberg spent six-month periods in 1966 and 1967 researching the ecology and behavior of tenrecs, a highly unusual family of primitive, insect-eating mammals. Of special interest was the discovery that the streaked tenrec is able to communicate by "stridulating"—that is, it makes a noise by vibrating a patch of specialized quills in the middle of its back. Akin to the clucking of a mother hen, the signal seems to help a foraging female tenrec maintain contact with her young as she roots in the dirt.

The Madagascar field research permitted the National Zoo to exhibit a number of rare mammals that were imported from the island, including the Malagasy civet, the ring-tailed mongoose, and the fossa. First-time breeding records were established for the latter two species.

Sri Lanka. Research in the island country of Sri Lanka began at the invitation of wildlife department officials, who wished to have their nation's elephant population surveyed. Work got underway in 1967 and involved Fred Kurt, George McKay, Melvyn Lockhart, and Eisenberg. The survey resulted in a number of seminal publications, including McKay's benchmark monograph on the biology of Asiatic elephants and the first studies of elephant reproductive biology and breeding behavior. Overall, the research effort represented the first systematic attempt to describe the ecology and reproductive behavior of this elephant species.

As work on the elephant problem progressed through 1970, the National Zoo also began to investigate Sri Lanka's primate and carnivore communities. Information about leopards, the purple-faced langur, gray langur, and Sri Lankan toque macaque was gathered by Muckenhirn, Suzanne Ripley, Gilbert Manley, Rudy Rudran, and Wolfgang Dittus. Dittus continues his Sri Lankan primate studies to this day (see p. 20).

The initiation of a training program was another notable aspect of Zoo work on Sri Lanka. Most of our senior staff members taught at the University of Ceylon, where an undergraduate program in animal ecology was established. Vegetation studies on the island paralleled our research and were the result of important cooperation between the National Zoo and the botany department of the Smithsonian's National Museum of Natural History. The involvement of most Zoo and Natural History personnel ended in 1971, but ecological research efforts have persisted on Sri Lanka, sustained by students such as Dittus and Rudran who were trained as part of the project. In some cases, our former students have joined the faculty of the national university.

Venezuela. The Venezuelan research project commenced in 1973 with a visit by Kleiman and Eisenberg to the capital city of Caracas. Following a period of negotiation, work began in 1975 with a comparison of the diverse ecosystems of Venezuela's plains (llanos) and its pre-montane forest. Colleagues on the project included M.A. O'Connell, Peter August, John Robinson, Mel and Fiona Sunquist, Rudran, Montgomery, Morton, and Carolyn Crockett. Our research yielded a wealth of data in such areas as the structure of small mammal communities, avian communities, and the population biology of howler and cebus monkeys. Significant advances included the discovery of and analysis of the causation of infanticide by red howler monkeys, a phenomenon which had previously been best documented in Asian langur monkeys. Additionally, studies of the function of howler monkey vocalizations, feeding ecology, and demography have led to a major increase in our understanding of howler monkey socioecology. Shorter studies have included observations of anteater behavioral ecology; crab-eating fox social behavior; and the function of fruit bat distress calls. The research continues to this day.

Nepal. Study of the population biology and ecology of the Bengal tiger in Royal Chitawan National Park was the primary aim of research in Nepal, which began in 1973. John Seidensticker was the first scientist on the project, followed by Mel Sunquist and David Smith. This phase of the project spanned some seven years, allowing scientists to gather valuable information on the land tenure sys-

tem, dispersal, and home range utilization of tigers through the groundbreaking use of radio telemetry techniques with a large carnivore. Christen Wemmer, Assistant Director for Conservation, became overall supervisor of the Nepal project and has expanded the ongoing research to encompass aspects of the population biology of deer, rhinoceros, and small carnivores.

Brazil. Ecological studies were initiated by James Dietz in the Poço das Antas Biological Reserve near Rio De Janeiro in 1983. This followed Kleiman's agreement with the Brazilian authorities that NZP could develop a program to reintroduce to the wild captive-born golden lion tamarins from the carefully managed international captive population. The reintroduction program has included studies of the structure and composition of the preferred habitats of golden lion tamarins, including the quantity and distribution of critical resources such as tree holes for nesting and bromeliads that harbor numerous invertebrates, an important dietary component for golden lion tamarins. Additionally, the Brazilian-American team is examining the processes of forest regeneration in deforested areas (Dionizio Morães Pessamilio); mechanisms to develop support for conservation by local communities through education (Lou Ann Dietz and Elizabeth Nagagata); methods for preparing and rehabilitating captive-born golden lion tamarins for survival in the wild (Ben Beck and Inês Castro); and methods of transplanting wild tamarins to protected areas (L. Pinder). New studies on the small mammal communities of different forest types, the genetics of golden lion tamarins, and energetics and metabolism are in progress.

North America. DZR field research was not confined to exotic locales; considerable effort also went into field projects involving North American mammals. Work was done in conjunction with the Chesapeake Bay Center on the biology of flying squirrels; Lang Elliot conducted a successful study on the Eastern chipmunk in the Adirondack Mountains; and with the 1975 acquisition of the National Zoo property in Front Royal, Virginia, a special effort was made to use trapping and radio tracking methods to study wild animals native to that area. In fact, such efforts are essential to work at the 3200-acre Conservation and Research Center, as free-ranging wild animals can easily transmit disease to the captive exotics housed in large, outdoor enclosures. Thus it is critical that native populations of foxes, raccoons, opossums, and skunks are continuously monitored.

During our research efforts, headed by Seidensticker, rabies broke out, and for the first time, in conjunction with Bush and NZP pathologist Richard Montali, a rabies epidemic was followed from its onset to its collapse in a wild population of raccoons.

The Front Royal facility has also provided numerous opportunities for work on local birds, with important investigations of bluebirds and Kentucky warblers conducted by Morton. Further studies of native animals, including white-tailed deer, star-nosed moles, and even slugs and snails, are currently underway at the Center. □

Jessie Cohen, NZP Graphics

Prior to their release into the wild, DZR's golden lion tamarins were carefully monitored in outdoor enclosures at the Zoo and later inside the Poço das Antas Reserve.

Morphology and Physiology

Mammal Mechanics

Steve Thompson and Ted Grand

In the Small Mammal House, an agouti quickly hops in and out among the roots and rocks of its enclosure, ceaselessly scouring the floor for tidbits of food. In another exhibit, the prehensile-tailed porcupine, protected by its coat of quills, spends much of the day resting on a branch in plain view. When the porcupine moves, it does so slowly, deliberately—in great contrast to the active agouti.

Across the hall, a short, bare-tailed opossum walks slowly along a branch; its day-old young are tiny, blind, and helpless, bearing little resemblance to the adult opossums they will eventually become. In yet another exhibit, young elephant-shrews, no older than the baby opossums, have already opened their eyes and are active, miniature versions of their parents.

Why are some animals so active, others so slow? Why do some mothers give birth to helpless young, while others give birth to young adults?

Many of the differences in activity and reproduction among mammals can be traced to the different ways these animals use energy. Thus, by examining how patterns of energy use relate to various aspects of morphology (how these animals are constructed) and lifestyle, we can better understand the vast range of differences we find among mammals, even in this small corner of the Zoo. This understanding is important for the proper care of animals in zoos and for their conservation and management in the wild.

A fur-covered skin is one of the most important characteristics of mammals. Although the primary purpose of fur is to keep animals warm, it also serves to camouflage the animal and protect it from injury and infection. The agouti has just enough skin (five percent of its weight) to cover its body so that it can move swiftly, unencumbered by a heavy coat, as it darts among the tangles of the forest floor.

By contrast, slow arboreal species, such as the prehensile-tailed porcupine or the sloth, have coverings that make up as much as 20 percent of their body weight. The porcupine's quills probably protect it from predators while the sloth's heavy coat provides camouflage and warmth, thereby permitting a lower idling level of energy use. Both the sloth and porcupine have relatively low resting metabolic rates, and probably as a consequence are slow moving and relatively inactive; thus their energy needs are in synch with the low-energy availability of their food (leaves).

DZR anatomist Ted Grand studies the relationships between an animal's physical structure and its activity and behavior; physiologist Steve Thompson studies the way these factors interact with the animal's internal workings.

Beneath the Skin

The outer covering of mammals is closely linked to what lies beneath the skin: the skeletal muscle that provides the power for movement. Terrestrial mammals that are very active, like the agouti or jackrabbit, are about 50 percent muscle. In the agouti, muscle is connected in a chain from the back legs to the shoulders so that the animal can explode into motion and make rapid changes in direction when startled or chased by a predator. Arboreal mammals such as the prehensile-tailed porcupine have less muscle (only about 30 percent of their total weight) than terrestrial mammals. The low muscle mass of arboreal mammals is probably related to their extensive use of leaves as a food, the small amount of movement required to obtain food, and perhaps also to a reliance on camouflage or defense, rather than speedy escapes, to avoid predation. Any of these explanations would reduce the need for the larger muscle required for prolonged, active movement. This pattern is not limited to arboreal vs. terrestrial species: In general, mammals that are very active tend to have lots of muscle and high resting metabolic rates while species that are relatively inactive have less muscle and require less energy to "keep their engines idling."

A comparison of two species will show how metabolic rate is also tied to mammalian reproduction. The short-tailed opossum is a slow moving, primarily terrestrial marsupial from South America while the elephant-shrew is a more active terrestrial animal from Africa. Both species put about the same amount of energy into their young and are about equally efficient at converting energy into offspring. The difference is that the opossum has from eight to ten young with very low growth rates and low resting metabolic rates during almost all of the lactation period. This prolongs the period of maternal care but probably reduces the use of energy. By contrast, the elephant-shrew infant has a high rate of metabolism and a high growth rate.

Why would these two different systems evolve? What are the advantages and disadvantages of each? Many speculative answers are possible for questions like these, but firm answers are what we hope to discover. We already know, for example, that the number of young and the way they are produced are influenced by the rate of development, which is determined by the rate of energy use, which is in turn affected by an animal's muscle mass, which is related to its food and activity. Learning how each of these factors interacts with the others will help us to understand better the differences among animal species and the evolutionary forces that molded them. □

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